ASTRONOMY

December 1993 U.S. $2.95
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Geminga:
The Star that Blew a Hole in Space

ICD 08070

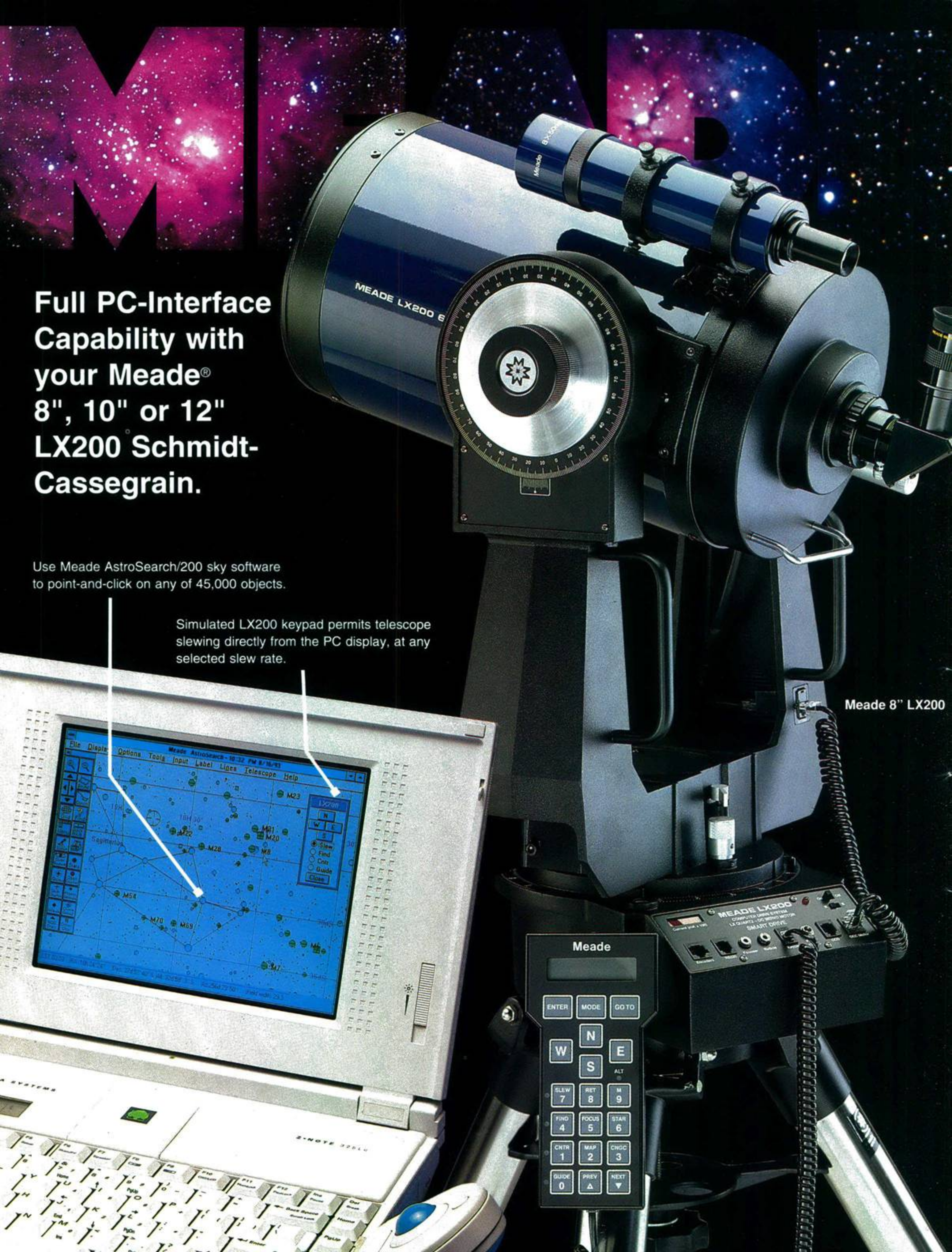
ORION'S SHOWPIECE NEBULA

TEST REPORT:
Two Fine Scopes for Beginners

Climb the Lunar Alps

Don't Miss the Geminid Meteors

- Mysterious Origins of the Martian Moons
- Death From the Sky: Asteroid Impacts


MEADE
MEADE LX200
Meade
ENTER
MODE
GO TO
N
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SLEW 7
RET 8
M 9
FIND 4
FOCUS 5
STAR 6
CNTR 1
MAP 2
CNGC 3
GUIDE 0
PREV
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Meade AstroSearch
LX200

Full PC-Interface Capability with your Meade® 8", 10" or 12" LX200 Schmidt-Cassegrain.

Use Meade AstroSearch/200 sky software to point-and-click on any of 45,000 objects.

Simulated LX200 keypad permits telescope slewing directly from the PC display, at any selected slew rate.

Meade 8" LX200

PC APPLICATIONS WITH MEADE LX200 SCHMIDT-CASSEGRAINS AND *ED* APOCHROMATIC REFRACTORS

Meade® AstroSearch/200™ sky software permits point-and-click, *fully remote* automatic telescope positioning to 45,000 objects.

One of the easiest and most enjoyable applications of Meade 8", 10" and 12" LX200 Schmidt-Cassegrains (or Meade CDS-driven *ED* Apochromatic Refractors) is the interface of a common desktop or laptop Personal Computer* (PC) to the telescope. It's this easy:

- Connect your PC to the LX200, using the PC port located on the LX200's power panel.
- Load Meade AstroSearch/200 sky software into your PC.

Equipped in this way, the LX200 becomes a powerful, PC-driven observing tool:

- Using the PC's mouse, just point-and-click on any of the 45,000 planetary, deep-space, or stellar objects now visible on the PC display, and watch as the LX200's powerful, high-torque control motors **automatically** move ("slew") the telescope at up to 8° per second on both axes, *precisely centering the object in the telescopic field.*

Remarkable applications as the above are made possible by the advanced technology built, as standard equipment, into every Meade 8", 10", and 12" LX200 telescope. Technology that far surpasses any other commercial telescope. Technology that has made these the largest-selling serious telescopes in the world.

*For safety reasons AC-powered personal computers should be used indoors only.

Meade 8", 10" and 12" LX200 SCT's (and #1697 CDS-driven ED Apochromatic Refractors) include an RS-232 serial port (PC connector) on the power panel.

Current (mA x 100)
MEADE LX200
COMPUTER DRIVE SYSTEM
LX QUARTZ – DC SERVO MOTOR
SMART DRIVE
On
Off
N
S
Encoders
RS232
Focuser
Reticle
Keypad
Power 12 vDC
CCD

Meade AstroSearch/200 sky software includes an extremely wide range of additional capabilities:

- **Point-and-click onto obscure, difficult-to-find objects**, including deep-space nebulae and galaxies as faint as 15th magnitude.
- **Print out your own star charts**—charts more detailed than any available in books. Zoom-in on the display and print out, at high resolution, small sky regions of particular interest.
- **Use the simulated LX200 hand controller** on the PC display for remote control of the telescope.

The Meade AstroSearch/200 celestial software package, supplied on 3.5" discs for Windows™ 3.1 or higher, is available from Meade dealers at $99.95**. Each package includes an 8 ft. PC-to-LX200 connection cable and an instruction manual with applications for Meade LX200 SCT's and *ED* Apochromatic Refractors.

Important new features now included as standard equipment with Meade 8", 10" and 12" LX200 Schmidt-Cassegrains!

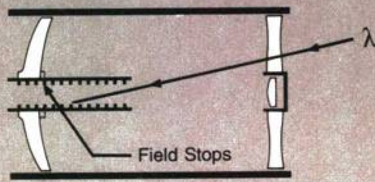
Every 8", 10" and 12" LX200 now shipped from the Meade Irvine, Calif., factory includes important new features that put these instruments even further into the forefront of modern astronomy:

- **2-Star Alignment without Tripod Leveling!** Quick-align the LX200 *in seconds* in the altazimuth mode without knowing your latitude or longitude, without even leveling the tripod! Just use 2 easy-to-find reference stars, and the telescope points and tracks with uncanny accuracy.
- **Two New Optional Object Databases:** Included with every LX200 is a basic 747-object database of the finest deep-space objects, reference stars, and the 8 major planets. New Meade *Version 3.20* LX200 software allows for two new optional object libraries:

—***Library Option 1:*** An object database of ***10,600 celestial objects*** taken from the Messier, NGC, and IC catalogs. Available at $99.**

—***Library Option 2:*** An object database of ***64,350 celestial objects,*** including the 10,600 objects of Library Option 1, above. Available at $149.**

- **Contrast-Enhancing Field-Stops—another Meade *first:*** All Meade 8", 10", and 12" SCT's now include a series of computer-optimized internal field stops, for greater rejection of unwanted stray light than ever before possible. These field stops, machined into the inside-diameter surface of the primary-mirror baffle tube *(see diagram)*, significantly increase lunar, planetary, and deep-space image contrast, compared to SCT's not so equipped.



Field-stops *(arrow)*, now included on Meade 8", 10" and 12" Schmidt-Cassegrains, significantly increase image contrast by effectively blocking off-axis stray light rays, λ.

Specifications: 8", 10" and 12" LX200's—Each complete telescope includes 8" or 10" (f/6.3 or f/10) or 12" f/10 SC optical tube assembly with super multi-coatings; heavy-duty fork mount with 4" polar ball bearing, dual-axis 5.75" worm-gears, and multi-function power panel display on the drive base; manual slow-motion controls on both axes; keypad handheld controller with digital readout display, PPEC Smart Drive, four-speed drive control on both axes, GO TO controller, and 747-object software library; 25 ft. power cord and adapter for telescope operation from 115v. AC (DC capability for operation from auto cigarette lighter plug available optionally); 8 x 50mm viewfinder with crosshairs; 1.25" diagonal prism (8", 10") or 2" diagonal mirror with 1.25" adapter (12"); Series 4000 Super Plössl 26mm eyepiece; standard field tripod (8", 10") or giant field tripod (12"); foam-fitted carrying case (8", 10") or foam-fitted thick-wall shipping carton (12"); complete operating instructions.

Supplied complete per catalog specifications**:

8" LX200 Schmidt-Cassegrain	**$2295.**
Equatorial Wedge 8"	**110.**
10" LX200 Schmidt-Cassegrain	**2895.**
12" LX200 Schmidt-Cassegrain	**3995.**
Superwedge 10"/12"	**395.**

Packing & shipping in 48 states: 8"–$105; 10"–$145; 12"–$215.

- **All prices shown are suggested USA mail-order retail prices, exclusive of sales taxes or credit card charges, if applicable.
- For dealer or catalog information see the Meade **Starfinder Reflecting Telescope** ad in this issue.

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ON THE COVER:
Wispy tendrils of red nebulosity accent the Orion Nebula, the most breathtaking emission nebula in the northern sky. To get a closer look at this winter delight, see page 74. © 1982 Anglo-Australian Telescope Board.

A PERSEID PLUNGES toward the horizon, one of the many brilliant flashes that helped make this year's shower special. For more great readers' photos, see page 68.

Dennis Anderson

20th ANNIVERSARY YEAR

ASTRONOMY

December 1993

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The
Audit
Bureau

Behind the Scenes

WINTER — ASTRONOMY'S IDEAL SEASON?

Call me a masochist, but I think winter is the best time of year for backyard astronomy. Okay, temperatures can get pretty nippy and horsing the telescope and mounting outdoors is more difficult with bulky clothing on. But the skies have such magnificent things to see!

Don't believe me? When else can you view the Orion Nebula? Summer's balmy nights have lots of other nebulae, but none are so attractive. Orion's glorious nebula is justly famous the world over. For centuries countless astronomers — professionals and amateurs, beginners and old hands alike — have reveled in the beauty of this cool flame of greenish light (page 74).

Nebulae such as Orion offer more than sheer visual delight. To astrophysicists armed with sophisticated and sensitive instruments, these are the wonderful places where nature makes stars out of clouds of dusty gas. The professionals' Orion Nebula differs from yours, but they can still overlap a little. As you look at the nebula in your eyepiece, let your mind journey outward. You can see the glowing hydrogen gas and dark dust clouds; now try to imagine what lies inside. Those clouds are far, far colder than the chill that's creeping into your toes and fingers. Yet deep in their darkness lie thick drifts where dust and gas are slowly warming into star-fire.

Another plus for winter skies is the easy visibility of the Moon. This puts more than 7 million square miles of geography high in the sky where trees and other obstacles interfere less with the view. Ever trace the rille that snakes down the Alpine Valley? Or set off on a telescopic journey — along the northern shore of Mare Imbrium, past the Teneriffe Mountains and Straight Range into Sinus Iridum, the Bay of Rainbows? This month offers a perfect opportunity (page 86).

December also brings the Geminid meteor shower (page 82). In recent years the Geminids have become the year's richest shower — excluding this August's fine Perseid display (page 68). Other grand winter sights include Sirius (the sky's brightest star), the unmistakable Pleiades cluster, and the soft glow of the Milky Way as it slips south on the left of Orion.

To me, summer nights make exploring the sky almost too easy. I seldom escape a sense of being outdoors, on Earth, looking into my telescope. In winter, on the other hand, it's easy to lose oneself in the eyepiece. Maybe it's because the chill in the backyard hints at the chill in space — or maybe the cold, white light pouring down from the Moon looks, well, more lunar than in summertime.

In any case, I make my stand: Winter's the best time of year for backyard astronomers!

Sincerely,

Robert Burnham
Editor

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Letters

Watching the Crystal Ball

I enjoyed the 20th anniversary article and letters (August 1993) and found the range of predictions incredible. I was amazed to read that some scientists believe in a steady state universe, especially following the COBE results of 1992 that supported the big bang theory.

Halton Arp's statement was the most surprising. After all, the steady state hypothesis fails to explain the cosmic microwave background radiation and the abundance of light elements in the universe. In the article itself not a single astronomer trumpeted the downfall of the big bang. That is proof enough for me that Professor Arp is out on a lonely limb. — *Georges E. Melki, Jeddah, Saudi Arabia*

The letters by Jack Sulentic and Halton Arp outlined the changes that must be made in order to build a credible view of the universe.

I cannot agree more with Arp's statement that extragalactic redshifts have been wrongly associated with distances to galaxies. Moreover, the important data for the Big Bang can be explained in other ways. Why not give the "alternate" ideas more time and funding to see if they are valid? — *Robert Farrar, Liverpool, England*

Light Pollution Victory

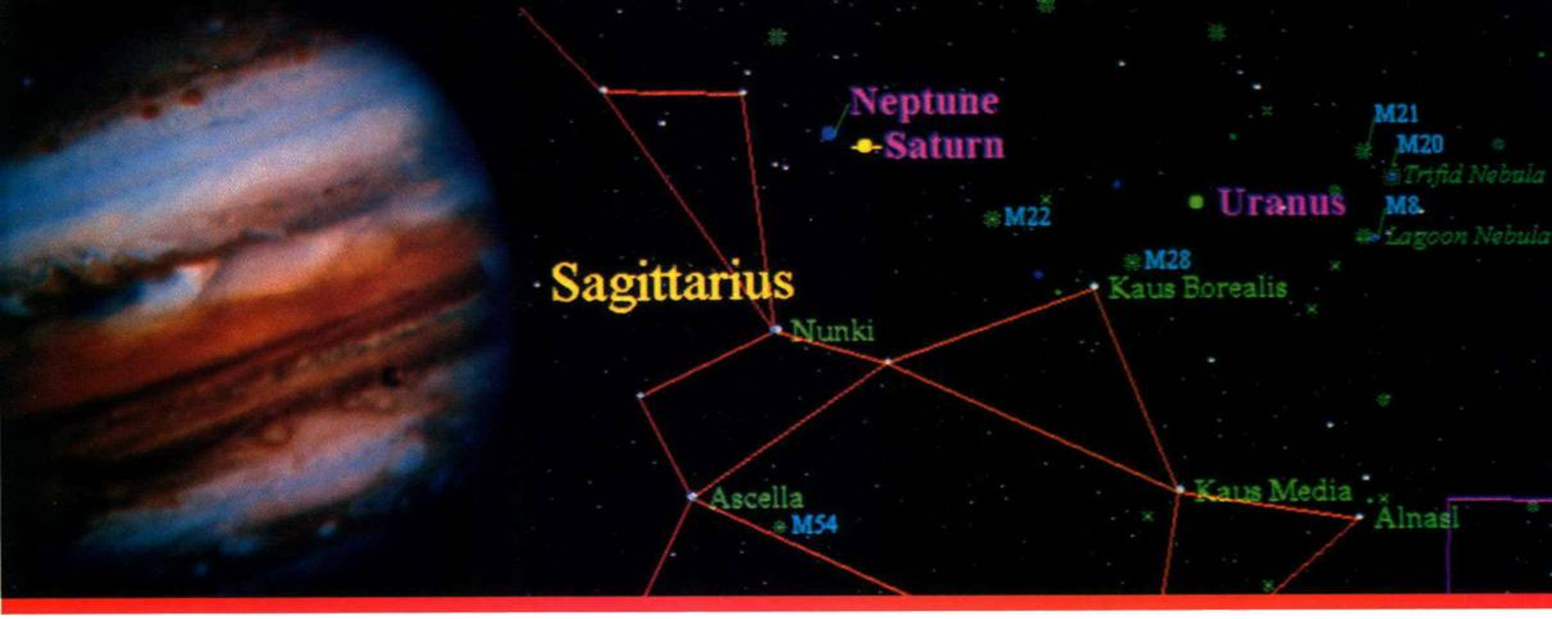
On June 9, 1993, Michigan Governor John Engler signed into law House Bill 4025, which created the Lake Hudson State Recreation Area. Located near Hudson, Michigan, the area is a dark-sky preserve. The legislation bans all unshielded lighting in the recreation area and we believe it is the first in the nation specifically designating a state park a dark-sky preserve.

Two of us from the Astronomical Society of Lenawee County recommended the legislation to Michigan Representative Tim Walberg, who enthusiastically supported the bill. The legislation overwhelmingly passed in the Michigan House (100-0) and Senate (37-1). The support was so encouraging that Rep. Walberg is considering introducing legislation reducing light pollution in other parts of Michigan. — *Wes Boyd, president, Astronomical Society of Lenawee County, Manitou Beach, Michigan*

What to Call CCD Imaging?

Robert Burnham brought up the question of what to call picture-taking by CCD. Your readers have responded in the letters columns of several issues.

[continued on page 12]


Neptune
Saturn
M21
M20
Trifid Nebula
M22
Uranus
M8
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M28
Kaus Borealis
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The universe so close you'll want to reach out and touch it.

What powerful and extraordinary astronomy program available for either Windows or DOS can bring you this close to the roiling clouds of Jupiter, to the stars, to the whole universe?

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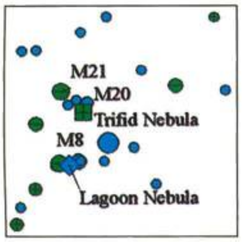

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What software allows you to plan observation sessions with professional-quality star chart printouts, locate whatever object on the screen you want, then guide your conventional or automated telescope to position the real one, dead on in your telescope?

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Place deep-space objects right in your eyepiece faster than ever with the telescope link.

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So for those who ever wondered at a falling star, or warmed to track the icy scarps of Neptune, or dreamed of sailing solar winds to distant galaxies and nebulae, where else is there to look?

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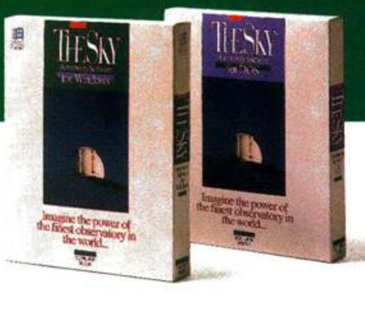
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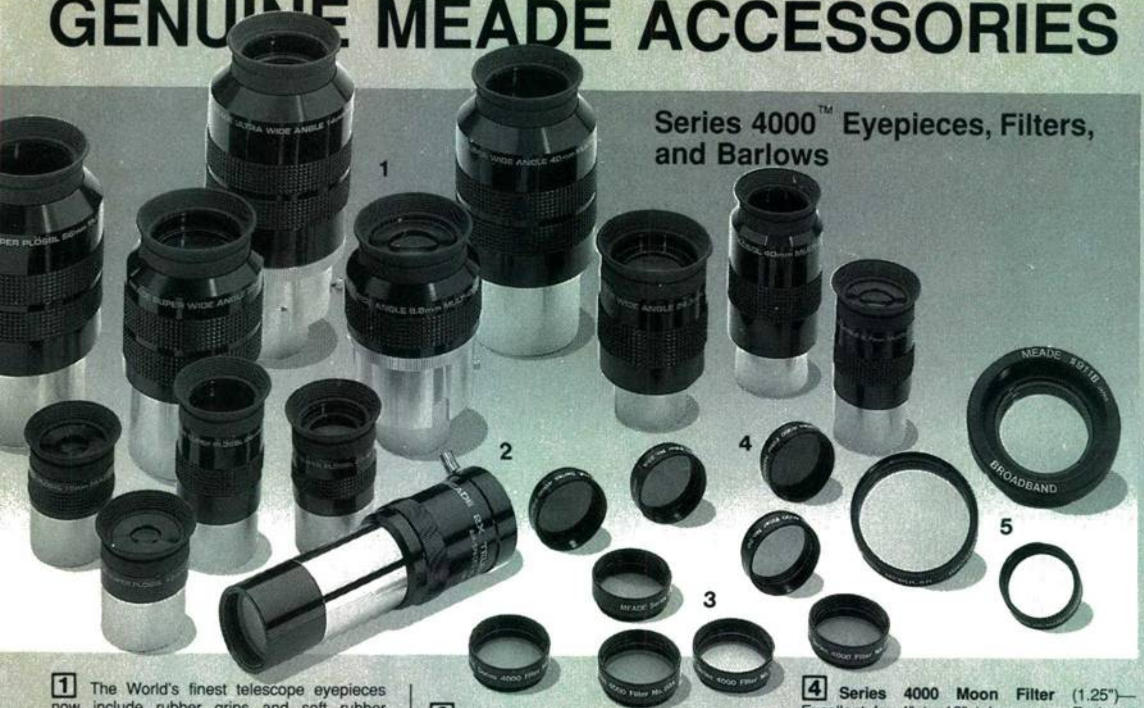

Series 4000™ Eyepieces, Filters, and Barlows

1 The World's finest telescope eyepieces now include rubber grips and soft rubber eyeguards for an even better observing experience! All eyeguards fold down for eyeglass wearers—a feature not available on competing brands. Best of all, **Meade Series 4000's are guaranteed to deliver more field, more contrast, and more image sharpness than any other brand at any price, or your money back.*** For splitting the closest doubles, revealing tenuous, faint nebulosity in deep-space, or studying hairline lunar and planetary detail, Meade multi-coated Series 4000's are the oculars that serious observers insist upon. ***"Clearly the best."***

Super Plössls (5-elements; 1.25"; 52°):
6.4; 9.7; 12.4; 15; 20; 26mm ea **$87.95** (3.29)
32mm(52°); 40mm(44°); each **109.95** (3.79)
56mm (52°, 2") **229.95** (4.18)

Super Wide Angles (6-elements; 1.25"; 67°):
13.8mm: **139.95** (3.29) 18mm: **149.95** (3.29)
24.5mm: **169.95** (3.79) 32mm(2"): **239.95** (4.18)
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4.7mm: **154.95** (3.29) 6.7mm: **187.95** (3.29)
8.8mm(1.25"/2"): **229.95** (4.18)
14mm(1.25"/2"): **269.95** (4.18)

*at participating dealers; see catalog for details.

2 #140: Series 4000 2x Apochromatic Barlow Lens (1.25")--The original Meade 3-element, air-spaced, multi-coated design. Absolutely unmatched in image resolution and color correction. 28mm dia. lens (26mm clear aperture). **$79.95** (3.29)

3 Series 4000 Photo-Visual Color Filters (1.25")—Made of purest crown optical glass, dyed in the mass. For increased contrast on the Moon and planets. Thread into virtually all 1.25" eyepieces sold today. Fully coated.

#8 Lt. Yellow; #11 Yellow-Green; #12 Yellow; #21 Orange; #23A Lt. Red; #25A Red; #38A Dark Blue; #47 Violet; #56 Lt. Green; #58 Green; #80A Blue; #82A Lt. Blue.
each **$12.95** (2.29)

Set #1—4 filters: #12 Yellow, #23A Lt.Red, #58 Green, #80A Blue **$49.95** (2.79)

Set #2—4 filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue **$49.95** (2.79)

Set #3—4 filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green **$49.95** (2.79)

Sets #1 & #2—8 filters **$89.95** (3.29)

Sets #1, #2, & #3—12 filters **$129.95** (3.48)

4 Series 4000 Moon Filter (1.25")—Excellent for 4" to 12" telescopes. Reduces Moon brightness by 87%. **$15.95** (2.49)

5 Series 4000 Nebular Filters—The very latest in multi-layer interference coating technology, Meade premium nebular filters are guaranteed to be the finest obtainable at any price. Use a Series 4000 Broadband filter to block most forms of light pollution, with minimal attenuation of desired wavelengths. Use a Narrowband filter in heavily light-polluted areas, or for extremely high contrast observing of faint nebulae.

BROADBAND FILTERS

#908B (1.25")—Threads into all Meade 1.25" eyepieces, and virtually all other brands. Full 26mm clear aperture. **$79.95** (2.49)

#910B—Threads into all Meade 2" eyepieces and most others; 44mm dia. **119.95** (2.79)

#911B--Threads on to the rear cell of Schmidt-Cassegrain telescopes. **99.95** (3.29)

NARROWBAND FILTERS

#908N (1.25")—Threads into virtually all 1.25" eyepieces; 26mm clear aperture. **89.95** (2.49)

#910N—Threads into all Meade 2" eyepieces and most others; 44mm dia. **129.95** (2.79)

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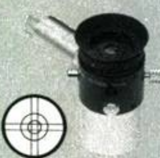
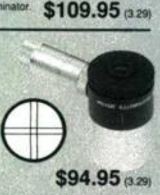
World's Most Advanced Illuminated Reticle Eyepiece



Series 4000 Plössl 9mm, with rubber eyecup and micrometric X-Y positioning of the reticle within the field. Greatly facilitates locking on the guide star. Sharp high-power imaging, excellent eye relief. Wireless red LED illuminator with adjustable brightness control. Internal batteries included. Multi-coated optics. Bullseye reticle. 1.25"
$129.95 (3.29)

Series 4000 Plössl 9mm—Same as above but with 6 ft. cord and plug for Meade LX3, LX5, LX6, LX100, LX200, and APO power panels, in place of wireless illuminator. **$109.95** (3.29)

MA 12mm Illuminated Reticle Eyepiece



Excellent 3-element optical system, long eye relief, fully coated, with double crossline reticle. Includes wireless red LED illuminator with internal batteries and variable brightness control. **$94.95** (3.29)

MA 12mm--Same as above, but with cord and plug for Meade telescopes with power panels, in place of wireless illuminator.
$74.95 (3.29)

2" Diagonal Mirror

#929: Permits use of wide-field 2" oculars. Threads on to rear cell of Meade and Celestron SCT's. Includes multi-coated precision optical flat made at the Meade factory; with 1.25" eyepiece adapter **$99.95** (3.29)

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Professional-quality adapters for rigid coupling of telescope-to-camera. Use for either Eyepiece-Projection or Prime Focus. Precision-machined of aluminum and brass, threaded for filters. Use with T-Mount, available separately.
.965": $27.95 (2.79) **1.25": $29.95** (2.79)

Variable-Projection Camera Adapter (1.25")

Machined sliding cell allows variable projection power in eyepiece-projection photography; permits precise selection of correct photo power in lunar and planetary photography; threaded for filters. Use with T-Mount for your camera. **$39.95** (2.79)

Tele-Extenders

TELE-EXTENDER

For Eyepiece-Projection photography with any Meade or Celestron SCT. Threads on to eyepiece-holder. Use with T-Mount for your camera.

Basic Tele-Extender: *(above)* Fixed projection power; use with eyepiece for lunar and planetary photos. **$29.95** (2.79)

Variable Tele-Extender: Sliding cell, with lock, permits wide range of projection magnifications with the same eyepiece.
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$26.95 (2.79)

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#122: Doubles eyepiece power with sharp, high-resolution, high-contrast imaging on telescopes of all types. 27mm dia. (26mm clear aperture). Excellent corrections for chromatic and spherical aberrations at all photo-visual wavelengths. Multi-coated. 1.25" **$47.95** (3.29)

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Fine 4-element oculars that yield excellent image quality with any telescope. Computer-optimized design provides wide, flat fields, highly corrected for spherical and chromatic aberrations. Parfocal, multi-coated, 1.25" barrels. Threaded for filters. **Focal Lengths: OR 4, 6, 9, 12.5, 25mm.**
each **$49.95** (2.79)

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An improvement on the traditional Kellner design, the 3-element MA gives sharp, faithful, well-corrected images of the Moon, planets, and deep-space. Multi-coated; threaded for filters. 1.25" **Focal Lengths: MA 9, 12, 25, 40mm.**
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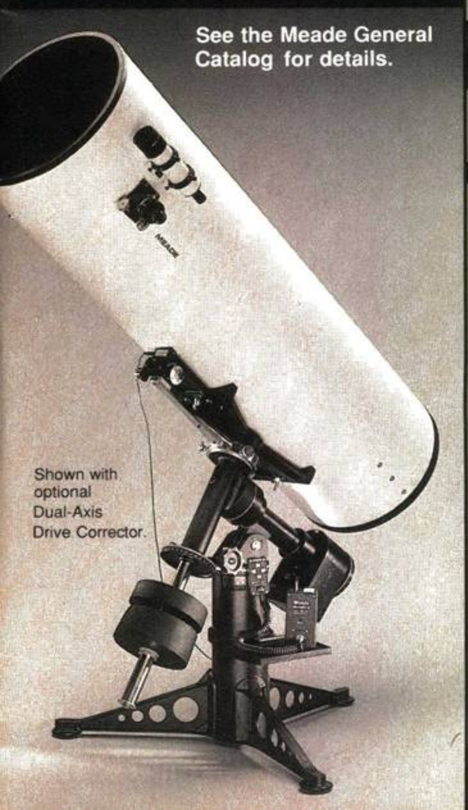

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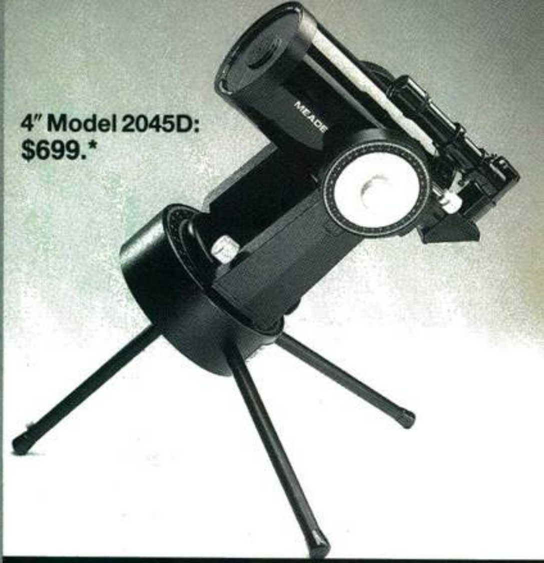

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Webster's Random House Dictionary defines *astro–* as "pertaining to stars or celestial bodies." The same source defines *photography* as "the process or art of producing images of objects on sensitized surfaces by the chemical action of light." Given these definitions, why not call CCD imaging astrophotography? — *Noah Romer, Kent, Washington*

Canon EOS Suitable for Astrophotography

In the article "Seeking the Best 35mm Camera" (September 1993), Alan Dyer claims that Canon EOS cameras are unsuitable for astrophotography. The reason he gives is that they will drain the battery during a long exposure.

The Canon EOS 650, however, uses a magnet rather than a battery to hold the shutter open during a bulb exposure. Battery power is required only for an instant when the shutter opens at the start of an exposure and again for an instant when the power disrupts the hold of the magnet.

While temperature effects are still a consideration, the Canon EOS 650 and its siblings (620, 630, RT, and 10s) are quite suitable for long-exposure astrophotography under normal circumstances. The 620, 630, 650, and RT have interchangeable focusing screens. The 10s has a fixed focusing screen but does have the advantage of mirror lock-up. — *John K. Greer, Universal City, Texas*

— Canon informed us that the EOS series, RT, and 10s cameras do not use a magnet to hold the shutter open — when opened or closed the shutter is simply at rest and requires no battery power. However, battery power is needed to trip the electromagnet that moves the shutter blades. Dependence on battery power for a critical function — and opening or closing a shutter is probably the most critical — makes any camera less desirable for astrophotography in cold weather. Canon also informed us that all the models Mr. Greer mentioned will soon be discontinued and replaced by models that do drain battery power during long exposures. The workhorse Canon F-1 still remains the best camera in the Canon line for astrophotography.

Mr. Dyer was incorrect when he stated the photographer's word *bulb* is a leftover from the days of flashbulbs. Old time shutters were operated by an air piston powered by a rubber bulb which the photographer squeezed. — *Hank Nicol, Eureka, California*

Keep it to yourself, man

The article "Gearing Up for the Perseids" (August 1993) suggested taking a boom box along with other observing accessories. I recommend that observers replace the boom box with a Walkman and headphones.

Just as I would object to someone who introduced light pollution into my observing environment, I would also object to noise pollution. Let the naturalists of astronomy enjoy the sounds as well as the sights of the night. — *Daniel W. Hart, Valparaiso, Indiana*

Lunar Eclipse Occultation Watch

The eclipsed Moon will pass through a rich Hyades star field 5° northwest of Aldebaran on November 29, 1993. This provides observers with an excellent chance to photograph the Moon against the star background and time occultations of stars around the entire disk of the Moon.

Such timings are important for lunar profile studies. These are in turn needed to refine analyses of solar eclipse contact timings used to investigate small variations in the Sun's diameter.

The International Occultation Timing Association can provide complete information about observing this event. Please call the IOTA information line in Greenbelt, Maryland, at (301) 474-4945. Observers who wish to undertake graze observations or timing occultations with large telescopes can request report forms and detailed predictions. Geographical coordinates including elevation above sea level are needed for accurate occultation data. We welcome readers of ASTRONOMY as contributors to IOTA. — *David W. Dunham, International Occultation Timing Association, 2760 Southwest Jewell Avenue, Topeka, Kansas 66611*

Correction

A color change resulted in an incorrect reference in the caption describing LQ Hydrae's magnetic fields in "Seeing a Star's Surface" (October 1993, page 36). The strongest fields appear yellowish in the map. ☐

ASTRONOMY welcomes suggestions and comments about articles and astronomy in general. Send your letters to ASTRONOMY Letters, P.O. Box 1612, Waukesha, WI 53187. Letters may be edited for length and clarity.

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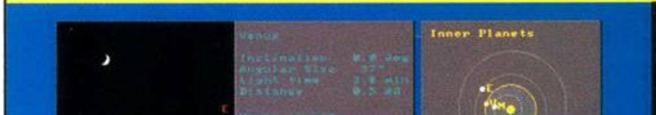

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Viewpoints

BEAR AND I HUNT GLOBULARS

by Wes Boyd

It had been beautiful and bell-clear all afternoon in Manitou Beach, Michigan, the clearest since the night a month or more before when I had found 30-some Messier objects with binoculars. I simply had to go observing. Yet I didn't have any companions that evening — my friends were all busy. And I think that observing is all about friendship. The universe is made for sharing.

The problem rolled around in my head as I ate supper, watched the news and weather, and picked up the evening paper. The front page of the "Lifestyle" section had a story about pets. There, right in the middle of the page, was a four-color picture of a couple of old friends. They were the caretaker of a local nature park and his big, black Newfoundland, Bear.

I picked up the phone to ask my caretaker friend if I could set up at the park picnic shelter and pull the breaker on the yard lights.

"Sure, c'mon over," he said.

The park is not the greatest location, but at least I'd have some companionship in the caretaker.

About 9:30 p.m., I pulled into the park. The caretaker lives in a house at the park, but when I arrived he was nowhere to be found. Neither was anyone else, except the dog.

"Bear, do you know you're famous?" I asked him as I opened my trunk and started hauling observing gear out. "Woof!" he replied, softly.

The best location at the park is a concrete deck outside an impressive picnic shelter, high on a hill, with a clear view to the southeast. In the gathering darkness I could see a little haze hanging low in the distance, but it didn't appear to be much of a problem.

Bear lay down and watched impassively as I carted observing gear from the car. My scope is a 6-inch f/5 built a dozen years ago that I have perched on a homemade altazimuth mount. It didn't take long to set up. Once I had the telescope set up and my star charts and accessory box out on the picnic table next to it, I went over to the circuit breaker box on a nearby pole and shut off the yard light, killing the annoying buzz that had filled the air.

The evening took on a whole different tone, one of peace and tranquillity. It was magnificent, if quite cool for July. I didn't hear a single cricket and heard only one disinterested mosquito. A gentle breeze blew over the park. I sat back on the picnic table, scratched Bear's head, and looked out over the prairie grass at the first stars popping into view. As the summer triangle of Deneb, Altair, and Vega began to make itself visible, I went over my observing plan for the evening.

I'd been looking at one Messier object or another for years but had decided the previous winter to re-observe the whole list. Over the past six months, I'd pretty well worked the list dry; on this evening, only nine remained that I hadn't seen since January. Tonight I knew I'd take a few more off that list.

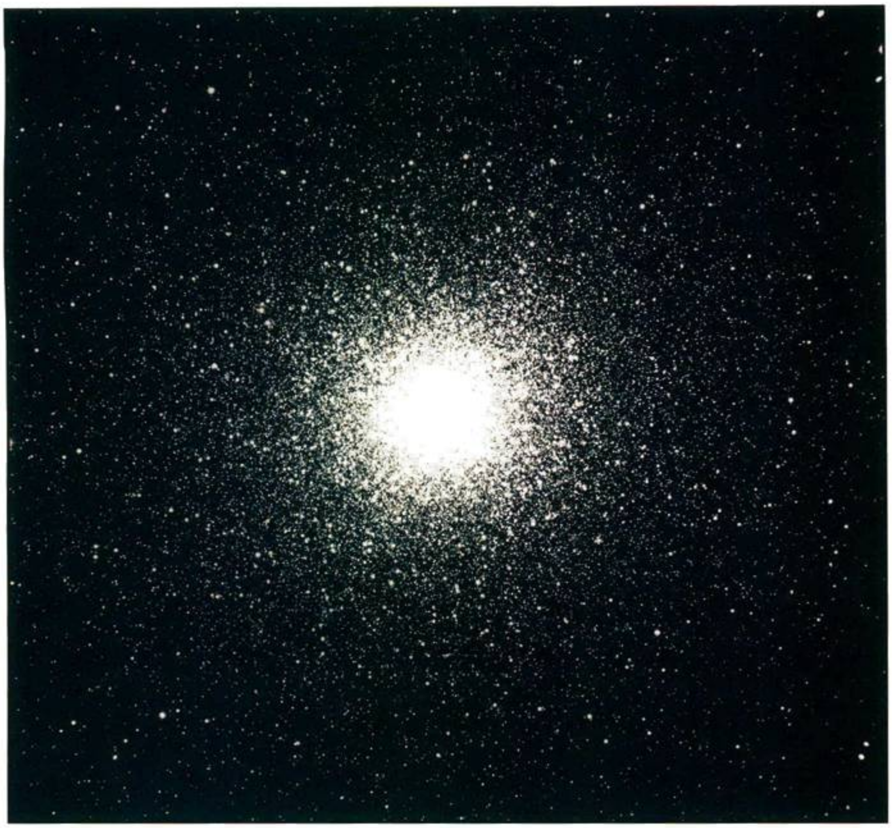
It took a little longer to get fully dark than I had expected. It was maybe 10:30 before I got under way, and it still wasn't completely dark. I could make out the teapot of Sagittarius, though, and that gave me the guide stars for my first target of the evening, the globular cluster M55.

Despite the breeze, the seeing was stable and the sky transparency was about as good as it gets around here. But I had a little trouble finding this globular cluster. Finally, I got to the area with the Telrad and swept with the 40mm eyepiece, much as Messier must have done. Finally the faint, fuzzy cluster came into the field. I changed eyepieces to the 18mm to zoom in.

I thought the next target, M75, was going to be even harder to find. However, I looked at the next chart and discovered that it was an easy starhop from Beta Capricorni. I was able to work my way to it in only a couple of minutes. This globular cluster was one of a handful of Messier objects that I had not seen before, and I hadn't realized that it was so small. My 18mm eyepiece showed its bright core and fuzzy halo quite well. "Bear, that's really pretty," I said to the black spot lying on the concrete a few feet away.

The next two targets, M15 and M2, were far north of Sagittarius and by now were getting well up above the horizon. Both were old friends. I discovered in an old observing log that they were the fourth and fifth Messier objects I had ever seen, after M31, M42, and M45.

Both of these globulars were easy starhops from bright stars, so I proba-



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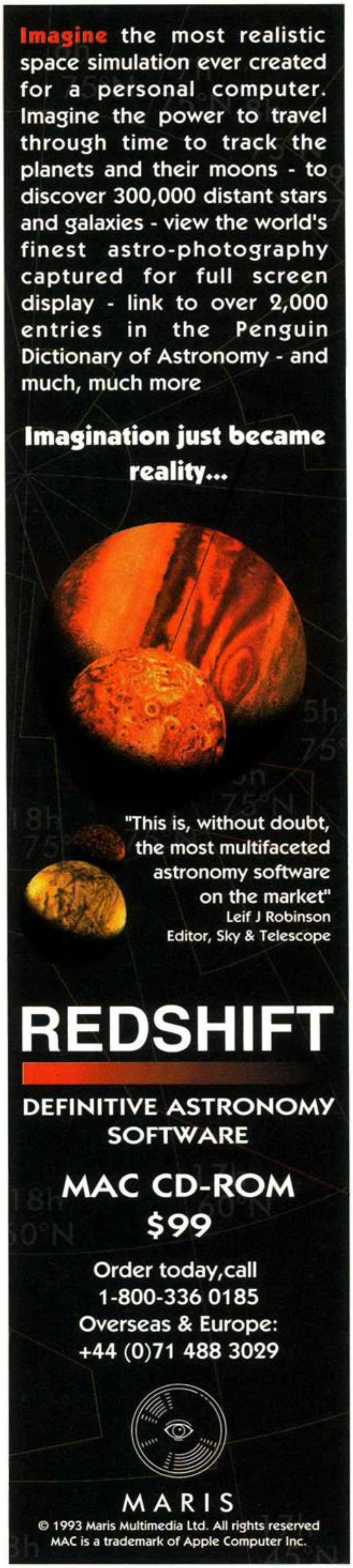

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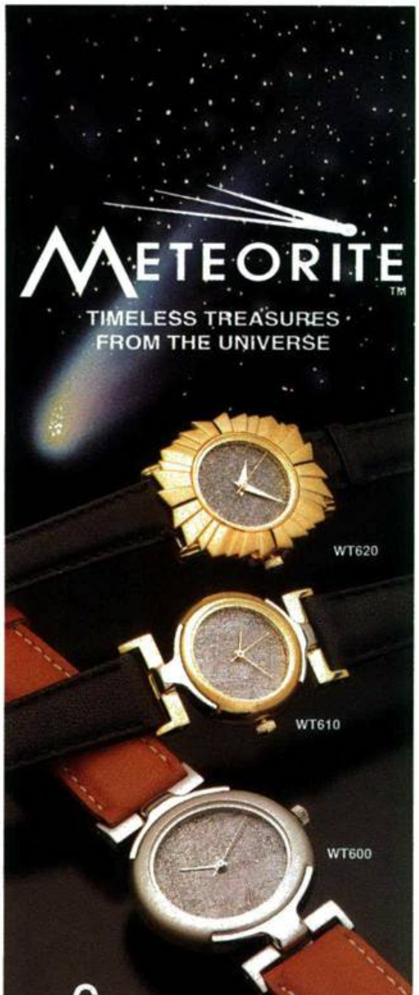

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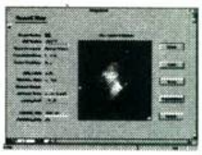

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bly took only a couple of minutes each to find them. It was much easier than the struggle I had had years before, when I was first learning to read star maps and use the telescope. Now I had a better idea of where to look and what to look for.

I boosted the power and was able to resolve some stars on the edges of M15. M2 is almost a twin to M15, fairly large and bright, and I spent a few minutes staring at it.

My concentration was broken by a little rustle off in the grass and a low-keyed "woof." A groundhog, probably, reminded by Bear to stay clear.

The next target, M72, took a little bit of finding. Even though there is a distinctive star pattern in the finder, it's not very obvious at low power, and it took a few minutes of scanning and changing eyepieces before I could say to myself, "Oh, yeah, there it is." With my highest power eyepiece, I thought perhaps I could resolve some of the stars at the edge of this small, faint globular. It was still fairly low in the sky, though, and I made a mental note to try it again some time when it was higher in the sky.

Reluctant to let the magic of the evening go, I slid the 40mm eyepiece into the focuser one more time and aimed down past the spout of the teapot. Then I moved the scope in the general direction of Cygnus, seeing all sorts of interesting things but not looking for anything in particular, just giving myself a treat for taking a chunk out of the list of Messiers.

I could not have been out long. It was only 11:30 p.m., or perhaps a bit later. I decided it was time to pack up, realizing that my Messier list had only three objects to go. All I needed to pick them off was one good night in the fall.

Not wanting to break the magic of the night, I tore the scope down in the starlight. I've had to do it often enough, so it was nothing special. Just as I was loading the telescope in the car, I noticed a mosquito, only the second of the evening.

Bear lay watching me until I had the last load in my hands. Then he followed me up to the car. Even he flinched from the sound of the transformer and the glare of the mercury vapor light as I threw the circuit breaker. He'd spent the evening with me, a good observing companion who stayed nicely out from underfoot.

"Bear, we'll have to do it again some time," I said, and headed for my car. ☐

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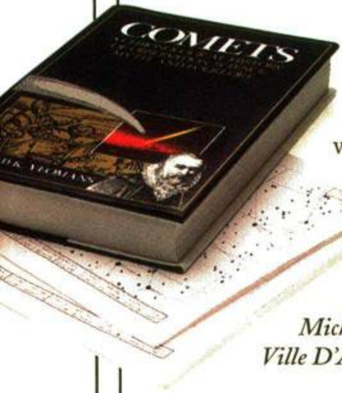

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Below - Captured Comet Shoemaker-Levy (1993e) impacting Jupiter, July 1994.

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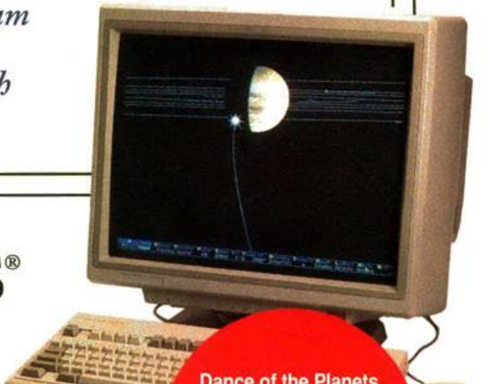

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UPDATE ON THE GREAT COMET CRASH

Mark your calendars. As we go to press, July 21 at 5 hours UT seems to be the best estimate of the date and time for the Great Comet Crash of '94. That is when the middle of the train of nuclei that forms Comet Shoemaker-Levy 9 will impact Jupiter. (See "Jove's Hammer," October 1993 for details.)

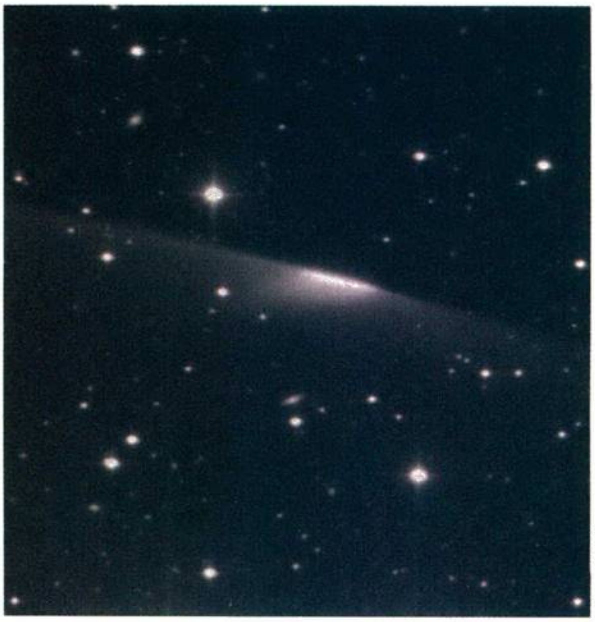
However, the train of 17 nuclei will take 5.6 days to strike Jupiter, the first components colliding with the giant planet on July 18 at 10h UT and the final components making the plunge on July 24 at 0h UT. All components will hit on the dark farside of Jupiter, out of sight from Earth. The impact sites will vary over a latitude of 41° to 47° South at a point roughly 35° east (toward the sunrise terminator) from the midnight meridian. About 90 minutes after each hit, the impact points should rotate into view as seen from Earth.

In the days just prior to impact, the string of Shoemaker-Levy's nuclei will stretch across 12 arcminutes of sky, slightly less than half the Moon's diameter. This translates to a physical length of some 30 million kilometers.

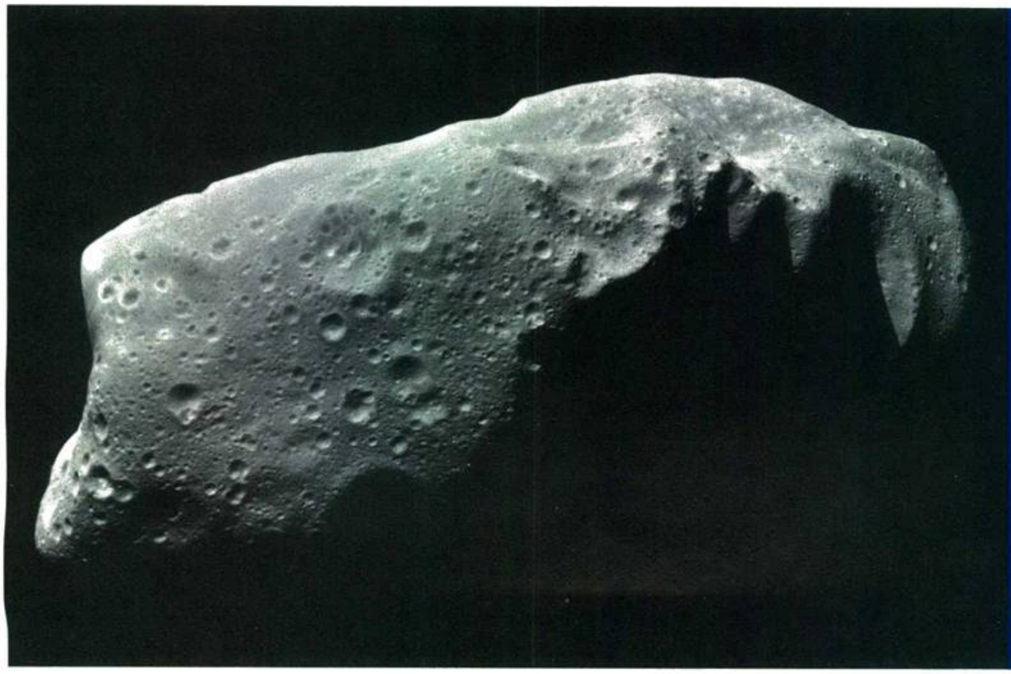
How much of an effect the comet impacts will have on Jupiter is the topic of debate. The key unknown is how big the nuclei are. If the largest chunks of Shoemaker-Levy are five km across (images taken recently with the Hubble Space Telescope suggest three to five km), the objects should penetrate deep into the upper atmosphere where they will detonate suddenly with a force of 500 million megatons of TNT. This is roughly equal to the amount of energy Jupiter receives from the Sun in a month. Each impactor will punch a hole through the atmosphere. Inrushing material will then shoot back up the tube at supersonic velocities and be ejected into nearby space.

However, the effects will be less if the chunks of Shoemaker-Levy are smaller. Some models of Shoemaker-Levy's breakup in 1992 suggest that the original intact comet may have been only two km across. If that is the case, the largest fragments could be no more than 500 meters across. Even if the nuclei are this small, the impacts are still expected to create visible effects in the cloud systems of Jupiter.

More detailed predictions won't be possible until after Jupiter and the comet emerge from behind the Sun in early 1994 and astronomers can obtain new images with both ground-based telescopes and Hubble.


A CLOSE APPROACH of Comet Shoemaker-Levy 9 to Jupiter on July 8, 1992, tore the comet into at least 17 fragments. All are expected to hit Jupiter in July 1994.

James Scotti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Galileo Looks at Ida

THE ASTEROID 243 IDA is a heavily cratered rock 52 km long as imaged by the Galileo spacecraft on August 28, 1993. Ida is the second asteroid encountered by a spacecraft and it is far larger and more heavily cratered than the first, Gaspra. This cratering implies Ida is relatively older than Gaspra. The resolution in this image is 31 to 38 meters per pixel. More images of Ida will be returned by the spacecraft from April through June 1994.

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IS THE
BIG BANG THEORY

?

WHAT IS
A BLACK HOLE

?

DOES
PLANET X
EXIST

?

WHAT CAME
BEFORE THE
BIG BANG

?

HOW MANY
GALAXIES ARE
IN THE UNIVERSE

?

HOW DO WE
KNOW THAT
THE UNIVERSE
IS EXPANDING

?

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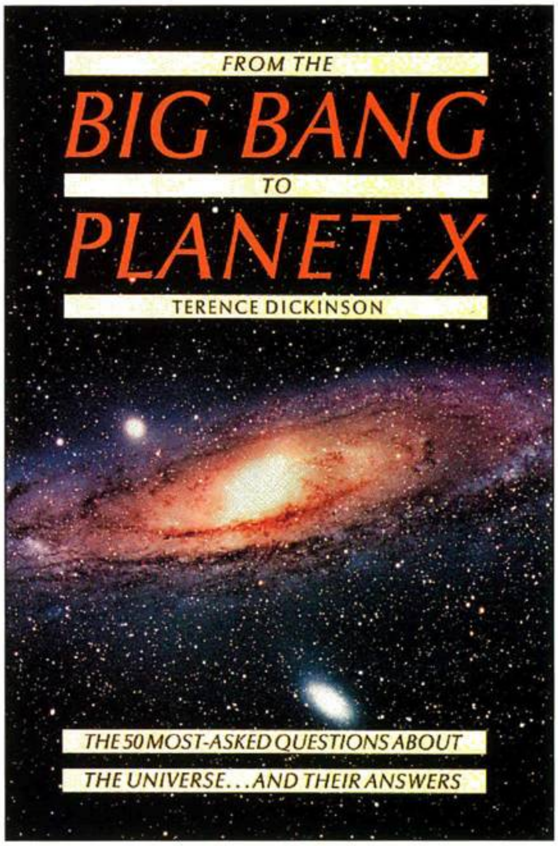
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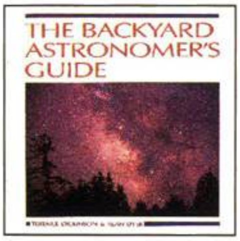
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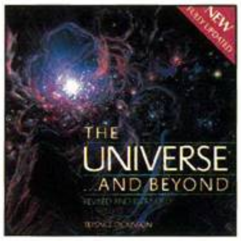
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SURVEYING THE EXTREME ULTRAVIOLET

The extreme ultraviolet part of the spectrum, lying between X rays and ultraviolet light, was the last place astronomers expected to observe astronomical objects. The Extreme Ultraviolet Explorer (EUVE), launched in June 1992, has shown just how wrong that idea was.

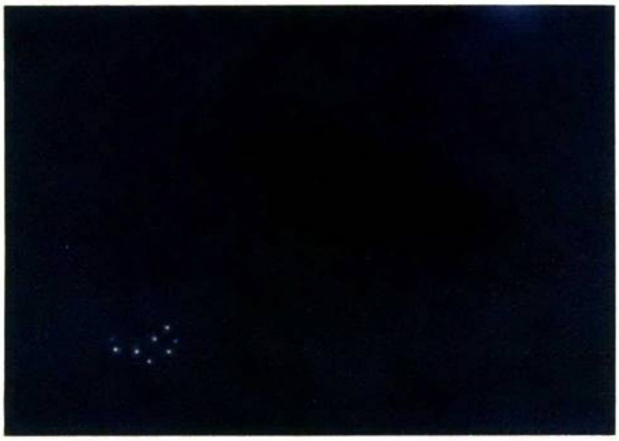
Instead of a featureless sky, astronomers at the University of California's Center for Extreme Ultraviolet Astrophysics in Berkeley have found hundreds of objects that glow brightly in the extreme ultraviolet. The brightest object is Epsilon Canis Majoris, a bluish-white giant star that lies 490 light-years from the Sun. The most distant object detected by EUVE is a quasar called Q 0239-591, in the constellation Horologium. It's a powerful source of energy lying about 10 billion light-years from us. The ten active galaxies detected by EUVE were unexpected because astronomers thought hydrogen gas in the galaxies themselves would absorb all their extreme ultraviolet emission.

For the first time, EUVE detected ionized helium (helium with one of its two electrons removed) in the interstellar gas. Ionized helium doesn't show its signature in visible light, so its presence was the subject of conjecture until now. Astronomers found that 25 percent of the helium is ionized. Because it takes high-energy radiation to ionize helium, hot white dwarfs or the remnants of ancient supernovae must be bathing the interstellar gas with their intense light.

Most of the objects EUVE has seen are stars, primarily active stars and hot white dwarfs. The active stars have strong magnetic regions on their surfaces just like the dark, cool spots on the Sun's surface. These regions heat the outer layers of a star's outer atmosphere or corona to over a million degrees. Hot regions within the corona emit the extreme ultraviolet radiation.

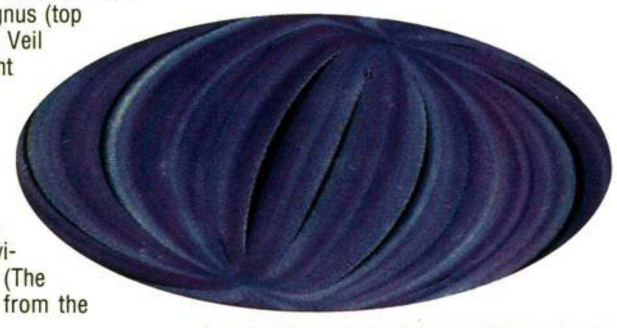
The atmospheres of white dwarf stars with temperatures over 35,000 kelvins should also emit strongly in the extreme ultraviolet. But researchers have found that iron, carbon, and other elements in the star's atmosphere absorb the extreme ultraviolet radiation. Previously astronomers thought that these elements would sink to the center of a white dwarf. But the strong radiation of a white dwarf apparently "levitates" the elements into the atmosphere. This discovery will help astronomers better understand other aspects of the spectra of white dwarfs.

These findings are just a sampling of the results obtained from the first year of EUVE's operation. Astronomers will busily spend the next few years mining the riches of the extreme ultraviolet universe — perhaps finding other unexpected sources of this radiation.



Center for EUV Astrophysics, University of California, Berkeley

THE GAS BETWEEN STARS glows faintly in the extreme ultraviolet, as seen by NASA's Extreme Ultraviolet Explorer Satellite. This artist's rendering shows a gas cloud in the constellation Taurus that absorbs this radiation, forming a dark shadow. The Pleiades appear at left. The gas cloud lies 200 light-years away.



THE EXTREME ULTRAVIOLET SKY mapped by the EUVE satellite contains hundreds of bright objects such as the supernova remnants Vela (bottom left) and Cygnus (top right, which includes the Veil Nebula). The Moon, caught on many different days during the mapping observations, created the wavy line of dots running through the middle of the map. EUVE also picked up the strong ultraviolet glow of Orion's stars. (The cross hairs at top result from the calibration procedure.)

Center for EUV Astrophysics, University of California, Berkeley

PARENT OF COMMON METEORITES FOUND

The inner solar system is filled with rocky debris created by asteroids colliding with one another. Some of that debris eventually reaches Earth and some even survives the fiery trip through our atmosphere to end up on the ground as a meteorite. At least that's where astronomers think meteorites come from. But fully 80 percent of all meteorites belong to the class known as ordinary chondrites, for which no parent body had ever been found.

Now Richard Binzel of the Massachusetts Institute of Technology and his colleagues have identified a small asteroid having the same spectral signature as ordinary chondrites. Known as Boznemcová, this 7-km-wide asteroid lies near the inner edge of the asteroid belt that stretches from beyond Mars to near Jupiter. This is a region where Jupiter's gravity can easily perturb an asteroid — or broken-off pieces of an asteroid — into an orbit that can intercept Earth.

Boznemcová can't be the whole answer, however. There are far too many chondrites for this one small asteroid to be the lone parent. Where are the others hiding? Most likely Boznemcová is either the tip of an iceberg of similar-sized bodies or it has a few larger siblings, presumably covered by a thin layer of debris that hides their unique spectral signature. We won't learn the answer until astronomers gain more observing time on larger telescopes to conduct an in-depth survey of asteroids.

PULSAR PLANETS?

In 1992 Aleksander Wolszczan of the Arecibo Observatory in Puerto Rico and Dale Frail of the National Radio Astronomy Observatory in Socorro, New

(continued on page 24)

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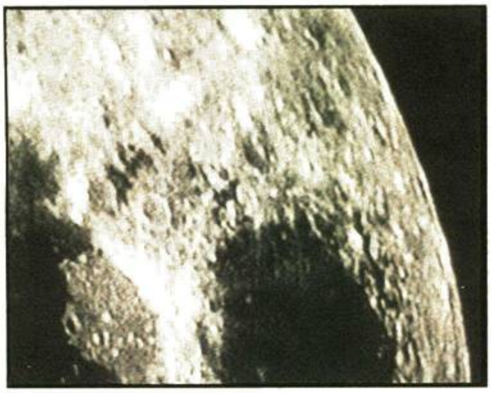

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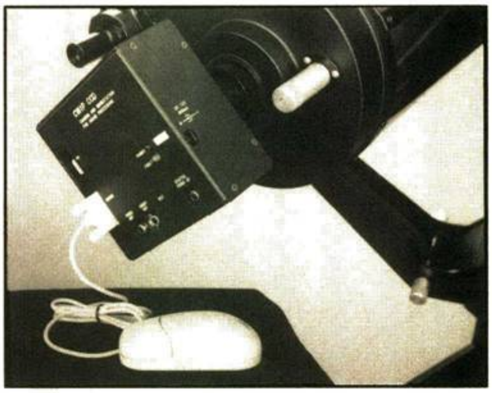

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"Dear Mr. Christen,

The new STARFIRE EDT arrived a few days ago. It was a joy to unpack it and to set it up: it looks beautiful and bears testimony of exquisite craftsmanship throughout. Yesterday the sky cleared up and the telescope got first light. I was out under the stars for many hours — looking, testing and also comparing the new instrument with other telescopes. Yet I soon realized that there was no reason to use any other instrument: the STARFIRE simply was superior. Deep sky views were sharper, cleaner and more contrasty than I have ever seen. And best of all: with this instrument the problem of spurious color definitely is gone — incredible! Jupiter was quite a show at all magnifications I tried. What amazed me was how bright its disc looked even at high magnification, with the colors in the belt system readily visible. There was a wealth of detail, much more than I could have drawn: it was a totally satisfying night of observing. Thanks for a superb instrument."

105mm f6 Traveler EDT (4.1")
130mm f8 StarFire EDT (5.1")
155mm f9 StarFire EDT (6.1")
180mm f9 StarFire EDT (7.1")

Write or call for your free brochure with complete specifications and prices of our extensive line of mounts and accessories.

ASTRO-PHYSICS **Inc.**
11250 Forest Hills Road
Rockford, IL 61115
815-282-1513

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408/255-8770

Monterey Bay– Santa Cruz

2450 17th Ave., West Marine Building,
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1/2 block from the freeway at Soquel Avenue
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THE WORLDS' LARGEST CATALOG OF TELESCOPES, BINOCULARS & ACCESSORIES —

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Packed with a huge selection of quality telescopes, binoculars and accessories, all at low discount prices! Hundreds of exclusive items you won't find anywhere else. ***Only a small selection of our products are in this ad! Be sure you have our catalog.***

CELESTRON

Telescopes, Binoculars and Accessories —

See Catalog For Our Full Selection.

Orion is the #1 source for Celestron products! Our low, low prices can really save you a bundle! Whether you are considering a big telescope or a small one, or a binocular or accessory, chances are Orion has just what you are looking for. Celestron telescopes are available with a variety of mounts, including German-style equatorial or fork mounts, with a wide range of available drive systems.

A huge selection of models, in all price ranges, available for immediate delivery!

Schmidt-Cassegrains — Celestron pioneered these fantastic instruments, and has an enviable reputation for building unsurpassed, exquisitely fine Schmidt-Cassegrain optical systems.

Refractors — Celestron's high-performance refractors are superb all-purpose telescopes, for astronomical or terrestrial observing. Built to standards that far exceed other telescopes in their class.

Reflectors — Celestron's popular reflector telescopes feature superior optical performance and full-featured, precision equatorial mounts which permit a full complement of optional accessories including electronic drive systems.

TeleVista II 60mm Refractor

Equally at home viewing the rings of Saturn or boats across the bay. Quality 25mm (28x) 1.25"eyepiece, all metal optical tube and yoke mount, finder scope, adjustable tripod, diagonal prism.

#9075 **$239** (8.97)

Sky Explorer II 60mm Refractor

Ideal for lunar and planetary study, plus it's a powerful terrestrial telescope. 900mm f.l, 6x30 finder; star diagonal ; two eyepieces, equatorial mount; setting circles; tripod; and lighted accessory tray.

#9076 **$399** (13.22)

SpaceProbe II 4.5" Reflector

Great 4.5" f/8 reflector, ideal for planetary and deep space. Equatorial mount, slow motion controls, setting circles. 6x30 finder plus 25mm (36x) and 9mm (100x) 1.25" eyepieces. Deluxe tripod.

#9078 **$399** (22.19)

Sky Explorer II 80mm Refractor

Perfect for planetary and lunar observation. Bigger equatorial mount than competitive models, two 1.25" eyepieces, 6x30 finder, star diagonal, deluxe tripod and accessory tray.

#9077 **$577** (32.66)

New! *Orion*

6", 8", 10", & 12.5" Dobsonian Telescopes

#9901 **$299** 6" f/8
#9903 **$599** 10" f/5.6
#9902 **$399** 8" f/6
#9904 **$769** 12.5" f/4.8

Prices include precision helical focuser and 25mm Sirius Plossl eyepiece—a $100 value!

These prices are not a misprint! Ideal for both beginners and advanced astronomers, these great new scopes offer high performance and lasting value. Precision 1/8-wave accurate reflector optical systems are ideal for both planetary and deep space observation. Image quality rivals scopes selling for four times their price. Huge light grasp for superb images of faint celestial subjects. See the Great Nebula in Orion in incredible detail. Get lost in the cloud belts of Jupiter. Lunar craters so detailed, you'll think you're in orbit!

Precision Dobsonian-type mounts are the finest in their class. Teflon zero-backlash bearings make it a breeze to track objects without wobble or vibration. Much more stable than comparable equatorial scopes. Lightweight, rugged, easy to transport and set up. Complete instruction manual.

Built to last a lifetime. Primary and secondary mirrors are aluminized and SiO overcoated for durability. Cabinet-quality laminate finish resists dirt and moisture.

Packing & UPS Shipping to any address in the 48 states: 6"—$39, 8"—$49, 10"—$69, 12.5"—$79.

DEEP SPACE EXPLORER

Incredible Value!

Shown with optional finder scopes

The 6" model is the ideal beginner's or family scope - and is incredibly low-priced. Weighing only 29 lbs. complete, it's easily moved or handled by anyone. The 8" model offers 77% more light grasp, but is still a reasonable 39 lbs. and is only slightly larger.

The 10" and 12.5" models are perfect for those who can observe from darker sky locations. While heavier and larger than the smaller models at 68 and 85 lbs., they offer tremendous performance for their low prices.

MONEY BACK
If you are not completely satisfied with your purchase from Orion, for any reason.
100% SATISFACTION
Just return it in new condition within 30 days after delivery for a full refund.
GUARANTEE

Call Toll-Free 800-447-1001

Huge Selection of Astronomy Binoculars

50mm Orion Observer™ II Binoculars — 7x, 10x, & 12x

Fine quality, moderately priced binoculars, excellent for both astronomy and daytime observation. Fully coated optics, unique hand strap for a secure and comfortable grip. Include case and straps.

7x50 #9643 **$89.50** (4.44)
10x50 WA #9644 **$94.50** (4.44)
12x50 WA #9645 **$99.50** (4.44)

50mm Explorer™ Binoculars

High performance large diameter binoculars with BAK-4 prisms and multi-coatings. Great for both astronomy and daytime observation. Comfortable ergonomic body design. Include case and straps

7x50 #9306 **$117** (4.44)
10x50 #9308 **$127** (4.44)

New! 10x50 Orion UltraView™

The perfect binocular for eye and sunglass wearers. Extra-long 22mm eye relief and unique rubber pop-down eyepiece guard allows viewing with or without eyeglasses. Fully multi-coated optics provide high light transmission and maximum contrast compared to standard coated types. BAK-4 prisms. Wide 6.5° field of view. Close focus 16'. Weighs 32 oz. Includes case and straps.

#9351 **$159** (4.95)

New! 10x50mm Orion Vista™

Superb for long distance nature observation and astronomy. The image quality will amaze you even when compared to much higher priced binoculars. Fully multi-coated optics provide high-fidelity true color images without ghousting or other aberrations. Long 16mm eye relief and roll-back eyecups for eyeglass wearers. BAK-4 prisms. 5.3° field of view. Weighs just 28 oz. Includes deluxe hard carrying case, rain shield, lens caps, and straps.

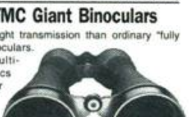
#9353 **$219** (5.19)

Orion® 70mm FMC Giants

The standard for hand-holdable astronomy binoculars. Fully Multi-Coated. 33% lighter—weighs only 58 oz.—yet the same brightness and 7mm exit pupil as our 11x80 MC model. Superior 'BCF' body design. Includes: soft rubber eyecaps, tripod mounting adapter, durable hard carrying case, lens caps and straps.

10x70 #9501 **Sale! $277** (6.97)
14X70 #9594 **Sale! $288** (6.97)

80mm FMC Giant Binoculars



20% more light transmission than ordinary "fully coated" binoculars. Fully Multi-Coated optics and superior BAK-4 prisms provide fantastic contrast and greatly improved edge sharpness.

11x80 MC- Brightest, widest field available. Ideal for deep-space observation under dark skies. Hand-holdable. #9502 **$379** (8.05)

16x80 MC- 45% higher power, excellent for astronomy and daytime observation. Tripod recommended. #9496 **$389** (8.05)

20x80 MC- Highest power model perfect for smaller deep-space objects and long range daytime views. Tripod required. #9498 **$399** (8.05)

Orion® 8x56 Mini Giants

56mm objective lenses gather over 2.5x the light of ordinary 7x35 binoculars. Perfect for viewing faint celestial objects, daytime viewing. Best Multi-Coated BAK-4 optics. 6° field of view. Standard model 33 oz. Rubber Armored for protection from bumps. Weighs 37 oz.

Standard Model #9504 **$159** (4.71)
Rubber Armored Model #9627 **$159** (5.07)

SuperGiant™ 100mm Binos

Gigantic, almost 4" lenses gather 156% of the light of 80mm binoculars. Individual eyepiece focus, fully Multi-Coated optics and BAK-4 prisms. Tripod mounting plate, metal-clad case. Weight 7.5 lbs., height 13.5".

14x100 #9495 **Sale! $777** (29.00)
25x100 #9497 **$899** (29.00)
Shipped by FedEx only.

Observing Aids

NEW! Eyepiece/Accessory Cases

With patented unbreakable latches, die-cut foam inserts.
Inside Dimensions shown
11"x7"x3" #5951 **$17.95** (2.78)
12.5"x9"x5" #5952 **$26.95** (3.36)
16"x11"x5" #5953 **$49.95** (5.19)

Orion® Dew Zapper

Gently replaces lost heat, a sure-fire cure for dew problems.

8" Dew Zappers —fit all Meade & Celestron 8" SCs
DC #3503, AC #3504 **$44.95** (2.98)

10" Dew Zappers—fit all Meade 10" SCs
DC #3506, AC #3508 **$49.95** (2.98)

11" Dew Zappers—fit all Celestron 11" SCs
DC #3510, AC #3512 **$54.95** (2.98)

Orion® FlexiShield™ Dew Caps

Forms into a tube with Velcro closure, opens flat for storage and travel. Models to fit most telescopes.

8" Celestron/Meade SC #4200 **$42.95** (2.98)

Other sizes available for scopes 3.5" to 14" —See our catalog for details

Scope Saver Telescope Covers

Keep the dust and dew away with these waterproof nylon covers; drawstring closure with cord lock.

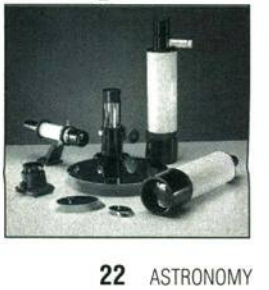
8"Model
#15130 **$33.95** (2.43)

10"-11" Model Fits Meade 10" and Celestron 11"
#15131 **$39.95** (2.43)

Now available for Deep Space Explorers!

Ask about other sizes.

Components



Parabolic Primary Mirrors

Excellent hand-figured parabolic mirrors guaranteed to meet theoretical limits of resolution. Fine polished, coated twice: with Aluminum and Silicon monoxide. Very competitively priced! *See catalog for pricing.*

Standard Primary Mirrors

Made from fine soda-lime plate glass, 1:8 thickness ratio. Guaranteed 1/8 wave. Sizes: 6" f/8, 8" f/6, 10" f/4.5, 12.5" f/6.

Pyrex Low Expansion Mirrors

Made from fine annealed Pyrex brand low expansion glass, 1:8 thickness ratio. Guaranteed 1/10 wave. Available with 94% reflectivity Enhanced Aluminum coatings. Sizes: 6" f/5, 6" f/8, 8" f/6, 10" f/4.5, 10" f/6, 12.5" f/6.

Elliptical Secondary Mirrors

Made from fine annealed Pyrex brand glass, aluminized and SiO overcoated. Guaranteed 1/10 wave accuracy. Available with Enhanced Aluminum coatings. Nine sizes from 1.00 to 4.00" minor axis. *See catalog for pricing.*

Finder Scopes New!

These are high-quality finders at incredibly low prices! Fully coated wide field achromatic optics with adjustable focus. Precision crosshairs. White or black enameled metal tube.

6x30mm — Same unit used on $1000+ "big name" telescopes. With 2-ring bracket, fits scopes 6"-12". #13023 (white) **$44.95** (3.41)

6x30mm Right Angle — 90° prism for right-angle viewing. Includes bracket. #13021 (white) **$59.95** (3.41)

8x50mm—2.7x light grasp of 30mm models. Bright 6.25mm exit pupil. #7090 (white) #7094 (black) **$64.50** (3.41)

8x50mm Illuminated—Wireless illuminator with adjustable brightness. #7092 (white) #7096 (black) **$94.50** (3.41)

9x60mm — 44% more light grasp than 50mm models. #7091 (white) #7095 (black) **$99.50** (3.41)

9x60mm Illuminated—Wireless illuminator with adjustable brightness. #7093 (white) #7097 (black) **$134.50** (3.41)

Mounting Brackets - Unique sliding dovetail design. Super high quality. Fits any scope 6" and over including Celestron & Meade SCs.

8x50mm bracket #5040 **$29.95** (2.98)
9x60mm bracket #5041 **$34.95** (2.98)

Rack-and-Pinion Focusers

Finest in their class. Diagonal-cut plated brass racks, oversized knurled knobs, long focus travel.

1.25" #13007 **$49.95** (2.98)

2.0" includes 1.25" adapter. #13003 **$89.95** (3.95)

NEW! Low-Profile Focusers

Perfect for fast optical systems. Ideal replacements for "Odyssey" scopes.

1.25"-#13014 **$39.50** (2.45)
2.0" - #13016 **$59.50** (2.98)

Night Vision Flashlights

An essential accessory for astronomers. Choose from our wide selection.

Astronomer's Flashlight #5701 **$9.95** (1.79)
Nitewriter Pen #5709 **$8.95** (1.79)
Hands-Free Flex Light #5707 **$17.95** (2.43)
Starlite LED Flashlight #5714 **$24.95** (2.43)
Celestron LED Flashlight #5720 **$21.95** (2.43)

Observer's Chairs

Standard Model—Adjustable height center column and padded seat. #5935 **$39.95** (4.70)

Deluxe Model—Built for professional musicians. Extra heavy duty. #5934 **$89.95** (8.02)

Accessories See Our Catalog for Even More!

45° Erect Image Diagonal Prisms

See the world as it really is with Orion's 45° erect image diagonal. Ideal for all refractors and compound telescopes used for terrestrial viewing.

1.25" Diagonal #8790
.965" Diagonal #8791
Hybrid 1.25"/.965" Diagonal #8792
$44.95 (3.45)

90° Star Diagonal Prisms

Orion's multi-coated diagon let you view at a right ang from the direction you telescope is pointing. The image is backward. Ideal for refractors and Schmidt-Cassegrains used for astronomical viewing.

1.25" Star Diagonal #8763 **$46.95** (2.98)
Hybrid 1.25"/.965" Star Diagonal #14008 **$31.50** (2.98)
.965" Star Diagonal #8761 **$28.95** (2.98)

2" Prism/Mirror Diagonals

2" Prism Diagonal–Absolutely the finest quality multi-coated 2" prism for highest light transmission.
For refractors #8770
For Schmidt-Cass. #8771

$199 ea. (4.71)

2" Mirror Diagonal– Affordable, high-quality star diagonal.
For refractors #8773
For Schmidt-Cass. #8772 **$99.95 ea.** (3.45)

Universal Camera Adapters

For prime focus or eyepiece projection astrophotography.

.965" #5268 **$26.95** (2.98)
1.25" #5264 **$28.50** (2.98)
Hybrid 1.25"/.965" #8782 **$28.50** (2.98)

Variable Power Camera Adapter

Allows variable projection distances during eyepiece projection photography. For 1.25" eyepiece holders.
#5262 **$38.50** (2.98)

Tele-Extenders

For high powered photography with your Meade, Celestron 4", 8", 10", 11", 14" Schmidt-Cassegrain.
Standard Tele-Extender #5125 **$27.95** (2.98)
Variable Tele-Extender #5127 **$37.95** (2.98)

T-Adapters

Threads to rear cell of telescope, requires t-ring for your camera model.
for SC #5116 **$26.50** (2.98)
for C-90 #7115 **$29.95** (2.98)

T-Rings

Available for many different camera types, call toll-free or see our catalog for your particular model.

Multi-Function Focal Tester

Allows easy, accurate, ultra-sharp focusing, essential for astrophotography.
#7109 **$169** (4.19)

Tripods

Bogen/Velbon/more!
Huge selection of tripods available, for telescopes, spotting scopes and giant binoculars. Choose from assembled models or mix-and-match pan heads and tripods, sold separately. See our catalog for details.

Orion Slow Motion Adapter

Attaches to your photo tripod pan head. 2 slow motion control knobs to make precision adjustments in altitude and altazimuth. Very handy for tracking planets, the Moon, etc. with refractor telescopes and small spotting scopes. Attaches with a standard 1/4-20 thread.
#7012 **$ 44.50** (2.98)

Extension Cable for Slow Motion Control

12 3/4" flexible cable, for tracking at high powers. Buy 2, one for each axis.
#5014 **$15.95 ea.** (2.43)

StereoScope Viewer

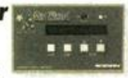
For comfortable two-eyes-open observing. You won't believe the views! Threads securely to the rear cell of your telescope. Requires two identical eyepieces.
#9720 **$479** (5.71)

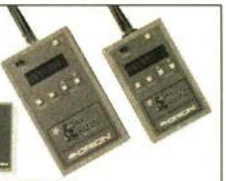
f/6.3 Reducer/Corrector

Get f/6.3 performance from your f/10 Schmidt-Cassegrain.
#5120 **$169** (3.67)

NEW Model 3 **Sky Wizard™**

Electronic Finder & Sky Catalog





Let Sky Wizard do the work, while you relax and have fun observing!

- Find any celestial subject in 15 seconds!
- One minute setup — no polar alignment or levelling.
- Observe hundreds of objects in a few hours!
- For ANY telescope, with or without a motor drive. *Even altazimuth or Dobsonian scopes!*
- Digital display of celestial coordinates (RA & Dec).
- Built-in electronic sky catalog — find subjects by their common catalog name, not their coordinates. Complete with object descriptions.
- Powered by a single 9v battery. Weighs just 6 oz!

Complete system requires Sky Wizard Model 1 or 2 and a telescope installation package, sold separately.

Encoders and cables available separately for custom installations. Call for details.

Sky Wizard Model 1
Includes the Messier Deep Space Catalog of 110 objects, 28 bright stars, and the planets.
#7801 **$199** (4.11)

Sky Wizard Model 2
Huge 2100+ object database, plus a user catalog to store 27 objects of your choice.
#7802 **$319** (4.44)

Sky Wizard Model 3
Gigantic 10,000 object database, expanded subject descriptions, RS-232 port.
#7803 **$469** (6.78)

Installation Packages
Includes 2 encoders, all required mounting hardware and brackets, connecting cables, and complete illustrated instructions.

Celestron Super Polaris	#27100	**$207**	(5.29)
Celestron Ultima 8" & 11"	#27101	**$177**	(5.29)
Celestron Great Polaris	#10303	**$314**	(5.29)
Celestron C-5	#10304	**$298**	(5.29)
Celestron G-11	#10305	**$329**	(5.29)
Celestron Classic 8" & Powerstar 8"	#27102	**$177**	(5.29)
Meade 8" & 10"	#27103	**$202**	(5.29)
Dobsonian (fits Coulter and most others) Call for stock # for your model		**$177**	(5.29)

Installation packages available for other telescopes.

Orion Off-Axis Guider

Allows you to observe a guide star during photography. Multi-coated.
#5144 **$69.50** (3.45)

Orion UltraGuider

Wide-range lateral prism adjustment; precision helical focusing; adjustable camera focal plane position.
#5139 **$119** (4.19)

110v Motor Drive for Refractors

Fits Orion equatorial mounts, many others. Plugs into any standard AC outlet.
#17001 **$72.50** (3.95)

12 Amp Hour Porta Pac Battery

Ideal for high power-consuming accessories. With carrying case. Weighs only 10 lbs.
#2354 **$109** (8.97)

Filters

Glass Solar Filters

High-quality optical glass filters, for superb images of the sun with your telescope. Triple-coated with advanced scratch-resistant stainless steel alloy. Great for both visual and photographic use. Slide fits over the front of your telescope.
For 8" SCs #7713 **$144** (4.05)
For 10" SCs #7715 **$162** (4.05)

NEW! *Solar glass filters for Deep Space Explorer reflectors. Many other sizes available—see our free catalog for details.*

Moon Filters

Cuts 87% of the light from the Moon. Reduces glare by uniformly reducing light transmitted over the entire spectrum.
.965" #5664, 1.25" #5662 **$14.95 ea.** (2.43)

Color Eyepiece Filters

Highest quality precision-ground optical glass. Fully anti-reflective coated. Solar system observations are dramatically improved. Thread into the barrel of any standard eyepiece, or directly into a universal camera adapter.

.965" Basic Set of 4 Filters #80A Blue, #58 Green, #25 Red, #15 Yellow
#5510 **$46.95 set** (2.98)

1.25" Basic Set of 4 *#80A Blue, #58 Green, #25 Red, #15 Yellow.* #5514
1.25" Expansion Set of 4 *#21 Orange, #47 Violet, #11 Yellow-Green, #82A Very Pale Blue.* #5516
1.25" Advanced Set of 4 *#8 Light Yellow, #23A Light Red, #38A Deep Blue, #56 Light Green.* #5570
$46.95 each set (2.98)

Deluxe Set of 8 Filters for 1.25" Includes all the filters in our basic and expansion filter sets.
#5517 **$79.95 set** (3.45)

Full Set of 12 Filters for 1.25" Includes Basic Set, Expansion Set, Advanced Set.
#5575 **$119 set** (3.67)

2" Set of 4 Includes #80A Blue, #58 Green, #21 Orange and #12 Yellow.
#5513 **$84.95 set** (3.96)

Individual .965", 1.25" & 2" Filters- Many colors available, see our catalog for details.

SkyGlow™ Light Pollution Filters

Enhance your viewing of faint deep sky objects with the best broadband light pollution filter you can buy. Our SkyGlow absorbs frequencies emitted by city lights, allowing transmission of the rest of the visible spectrum, yielding dramatic results.

SkyGlow Broadband Filters—Photographic and Visual
For use in slight to moderately light polluted areas.

1.25" Broadband Filter–fits 1.25" eyepieces.
#5660 **$69.95** (3.45)

SC Broadband Filter–fits rear cell of Meade & Celestron SC scopes.
#5658 **$89.95** (3.45)

52mm Broadband Filter–For 52mm camera lenses. (Adapter rings available for other diameters.)
#5668 **$87.50** (3.45)

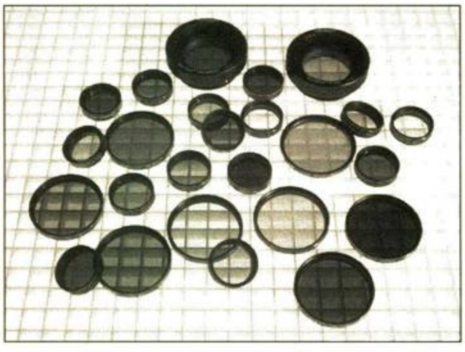
2.0" Broadband Filter–fits 2" eyepieces.
#5659 **$109** (3.45)

.965" Broadband Filter–fits .965" eyepieces.
#5661 **$49.95** (2.98)

SkyGlow UltraBlock Filters–Visual Only
For severely light polluted areas and faint nebulae.

1.25" UltraBlock Filter–fits 1.25" eyepieces.
#5654 **$87.50** (3.45)

SC UltraBlock Filter–fits rear cell of Meade & Celestron SC scopes.
#5656 **$119** (3.67)



Eyepieces & Barlows

✧ Sirius™ Plössl 1.25" Eyepieces

Fantastic Name-Brand Quality Eyepieces at an Incredible Low Price!

You could pay nearly twice the price for 'famous name' Plössl eyepieces, but we don't think you'll be able to tell the difference if you compare them to these fantastic eyepieces!

Sirius Plössls are top-quality, 50° apparent field eyepieces with extremely sharp images of impressively high contrast. Ideal for all types of reflector, refractor and catadioptric telescopes. The Plössl design is renowned for its fantastic performance and has in recent years become the standard by which all other eyepieces are compared.

Each eyepiece is of the classic 4-element Plössl design. Every air-to-glass surface is fully Magnesium Fluoride anti-reflection coated. All lens edges are blackened in the same way as expensive military optics, to further eliminate any scattering of stray light and to maximize contrast.

The optics are mounted in precision black anodized aluminum housings with chrome-plated brass 1.25" barrels for durability and precision fit.

We guarantee you'll be impressed with the performance of the Sirius Plössls, even when compared to the more expensive name-brand Plössls.

25mm #8530, *17mm* #8531, *10mm* #8532, *7.5mm* #8533 **$59.95 each** (3.45)

Special Savings-*Buy 2 or more & get case free!*

Any 2	*$54.50 ea.*	*SAVE $23.95*
Any 3	*$48.00 ea.*	*SAVE $48.80*
All 4	*$44.00 ea.*	*SAVE $76.75*

Case only #5911 **$12.95** (2.19)

Explorer .965" & 1.25" Eyepieces

These fine quality multi-coated eyepieces offer great performance at Orion's low direct-discount price. Three different optical designs are incorporated, to maximize efficiency in the various focal lengths. Black anodized, internally blackened, threaded for filters (except 40mm .965").

.965 Orthoscopic
5mm #8580, **7mm** #8581, **9mm** #8582, **12.5mm** #8583 **$49.50 each** (2.98)

.965 Kellner
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Mexico, discovered the first planets outside our solar system, orbiting around a pulsar called PSR 1257+12. This followed the "discovery" — and its retraction — of planets around a different pulsar by an English research team. (See "Lost and Found," June 1992.) Wolszczan and Frail interpreted changes in the period of the star's radio pulses as gravitational pulls by planets on the star.

Now Janusz Gil of the Astronomical Center in Góra, Poland, and coworkers at the Max-Planck-Institut für Radioastronomie in Bonn, Germany, question whether PSR 1257+12 has planets after all. In their opinion, published in the April (II) 1993 issue of *Astronomy and Astrophysics*, wobbling or precession of the neutron star's rotational axis is sufficient to explain the changes in the period of the pulsar.

Another possible pulsar planet may orbit PSR B1620–26, a pulsar in a binary star system. Stephen Thorsett of Caltech and colleagues at Princeton University have observed this pulsar located in the globular cluster M4 in Scorpius. Their data suggest that either a planet orbits about 10 times the average Earth-Sun distance from the neutron star or that a star orbits five times farther away. Whether the object turns out to be a planet or a star, it will be unique. Either the object will be the first planet discovered in a binary, or PSR B1620–26 is the first pulsar known to lie in a triple star system. It may take a decade to determine the orbit of the object and, thus, identify it as a planet or a star.

X-RAY BURSTER COMES TO LIGHT

Peering deep into the heart of the globular cluster NGC 6624 in Sagittarius, the Hubble Space Telescope has detected light from a strange double star prone to violent bursts of X rays. Although the X-ray bursts were discovered more than 20 years ago, this is the first time astronomers have seen the light.

The binary system consists of a neutron star — the extremely dense, compact corpse of a massive star that exploded long ago — and a larger but less massive white dwarf. The stars orbit each other once every 11 minutes, making this the fastest binary system known. They lie just 100,000 miles apart, less than half the distance between Earth and the Moon.

The neutron star's intense gravity strips helium from the outer layers of the white dwarf. The constant flow of this helium onto the neutron star releases a steady stream of X rays. But enough helium eventually accumulates on the star's surface to ignite spontaneously,

(continued on page 26)

Amateur News

PERSEIDS SPARKLE OVER STELLAFANE

Meteors from the Perseid shower provided entertainment for the more than 1,500 people who attended the 58th Stellafane convention in Springfield, Vermont. Held Friday, August 13, and Saturday, August 14, 1993, the gathering attracted amateur astronomers from New England but also from across the United States and Canada and from as far away as Europe and South America.

As telescope makers and observers listened to the talks on Friday and Saturday nights, loud oohs and aahs rang through the atmosphere as bright meteors zipped overhead. Although no Perseid storm occurred, as some astronomers had predicted, the number of fireballs that left glowing trains was surprising. When not distracted by meteors, Stellafane visitors heard talks covering a wide range of subjects, from astrophotography to telescope making to club observatories to deep-sky viewing. The formal talks on Saturday afternoon included Barry Levin's presentation on a homebuilt photometer, Jean Cross and Dann McCreary's description of a 20-inch, 20-pound backpack scope, and Robert F. Royce's report on a refractor he built from scratch.

Although meteors were visible on both nights, the weather could have been better. Thunderstorms rolled across the Stellafane grounds on Breezy Hill on both afternoons. The precipitation cleared out in time for observing but left the crowd in a damp and occasionally muddy situation during the evenings.

Saturday evening was special nonetheless. Famed deep-sky observer and author Walter Scott Houston delivered his annual "shadowgram," a monologue reflecting on the state of amateur astronomy and telescope building. The primary evening speaker was Don Parker of Coral Gables, Florida, who described his pioneering CCD imaging of planets. A Mars recorder for the Association of Lunar and Planetary Observers, Parker has over the past several years amassed a superb collection of electronic images of Mars and other planets taken from his backyard observatory. Parker showed numerous examples of these as he explained the CCD-imaging process.

Afterward Stellafane's happy lot scattered to the camping fields and the summit of Breezy Hill, unwrapped their telescopes, and turned their gaze skyward. The sky conditions may not have been perfect, but Stellafaners are hardly stopped by such small considerations.

ASTRONOMY: David J. Eicher

TELESCOPES AND SKYWATCHERS blanketed Breezy Hill during the 1993 Stellafane convention in Springfield, Vermont.

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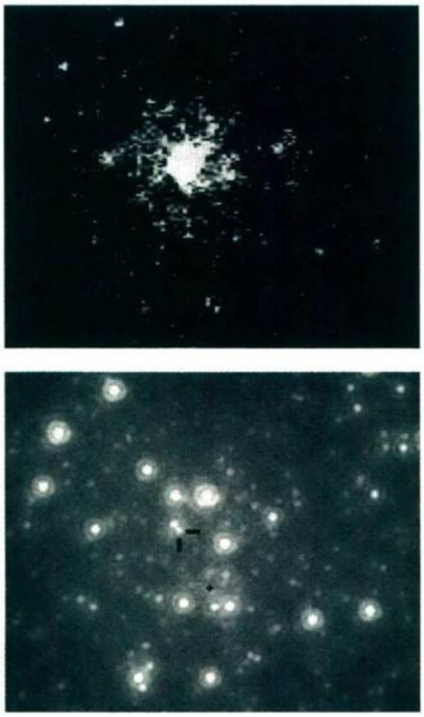
which powers the sporadic, intense X-ray bursts.

Ivan King of the University of California at Berkeley and his colleagues found the optical emission almost by accident. "I was just doing a routine study of the dynamics and population of stars in the cluster," says King. "My decision to take an ultraviolet image was a shot in the dark."

The neutron star is so hot that it radiates most of its light in the ultraviolet, far outshining all others in the cluster's core. The high resolution and sensitivity to ultraviolet light of HST's Faint Object Camera allowed the astronomers to distinguish the star from others crammed together in the dense core.

King now plans to use Hubble's High Speed Photometer to look for brightness changes during the binary's 11-minute orbit. He also wants to look at optical wavelengths for the mysterious flickering seen in X rays, a flickering that occurs 30 to 40 times per second. "There is only a remote hope of seeing something in that range, but we can't afford not to look."


Ivan King (UC at Berkeley) and NASA/ESA

FAR BRIGHTER THAN THE AVERAGE STAR, at least in ultraviolet light, is an X-ray burster in globular cluster NGC 6624 (top). But HST also captured the burster, a binary system consisting of a neutron star and white dwarf, in optical light (above). Tick marks identify the burster, which lies 0.1 light-year from the cluster's center (cross).

FOUR NEW PLANETESIMALS DISCOVERED

The number of known icy planetesimals orbiting beyond Neptune jumped from two to six during September. Jane Luu (Stanford University) and David Jewitt (University of Hawaii) found the first pair on CCD images taken with the 2.2-meter telescope on Mauna Kea.

The first, 1993 RO, shone at 23rd magnitude at discovery on September 14. The second, 1993 RP, was found a day later and at two magnitudes fainter. Preliminary orbits place 1993 RO about 32 AU from the Sun, making it the closest of the objects discovered so far. 1993 RP lies about 35 AU from the Sun.

Then, between September 16 and 21, Iwan Williams (Queen Mary College) and Alan Fitzsimmons and Donal O'Ceallaigh (Queen's University, Belfast) discovered 1993 SB and 1993 SC with the 2.5-meter Isaac Newton telescope on La Palma. These objects' magnitudes were 23rd and 22nd, respectively. Preliminarily, 1993 SB lies 33 AU from the Sun; 1993 SC is at 34 AU.

Astronomers suspect a huge number of small, icy bodies lurks beyond the orbit of Neptune. When Luu and Jewitt found the first, 1992 QB_1, most astronomers saw it as the tip of the iceberg (see "A New Member of the Family," December 1992). Now, with six objects, they are beginning to see below the surface. ☐

Space News

HIPPARCOS MISSION ENDS

Switching off is hard to do. But on August 15 scientists at the European Space Agency (ESA) shut down operation of its Hipparcos satellite, its mission accomplished. During its four-year flight, Hipparcos measured the positions of more than 100,000 stars with an accuracy of one to two thousandths of an arcsecond. By contrast, the resolution of the typical amateur telescope is about one-half to one arcsecond. Hipparcos discovered thousands of new binary stars and charted the light fluctuations of hundreds of thousands of variable stars. It also measured the velocities of stars through space to a precision of several hundred meters per second.

The Hipparcos Star Catalogue, expected to be completed in 1996, will provide astronomers with star data 10 to 100 times more accurate than can be routinely determined from the ground. Compiling this catalog will be the largest data-processing task ever undertaken in astronomy.

The success of Hipparcos is all the more remarkable considering that after its August 1989 launch, a failure of a booster rocket left Hipparcos stranded in the wrong orbit. Instead of circling 36,000 km above Earth in a geostationary orbit, Hipparcos looped around Earth in a 500 km by 36,000 km elliptical path. While engineers were able to redesign the mission and accomplish the original goals, the repeated passages through the radiation of the Van Allen belts eventually took their toll on the spacecraft's electronics. Ground controllers lost contact with Hipparcos on June 24. After attempts to reestablish contact failed, ESA terminated the mission.

ESA

MAPPING THE STARS was the mission of the European Hipparcos satellite, which *ended its four-year mission last August.*

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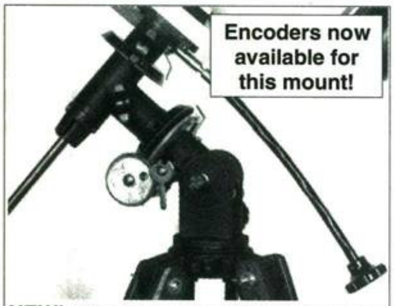

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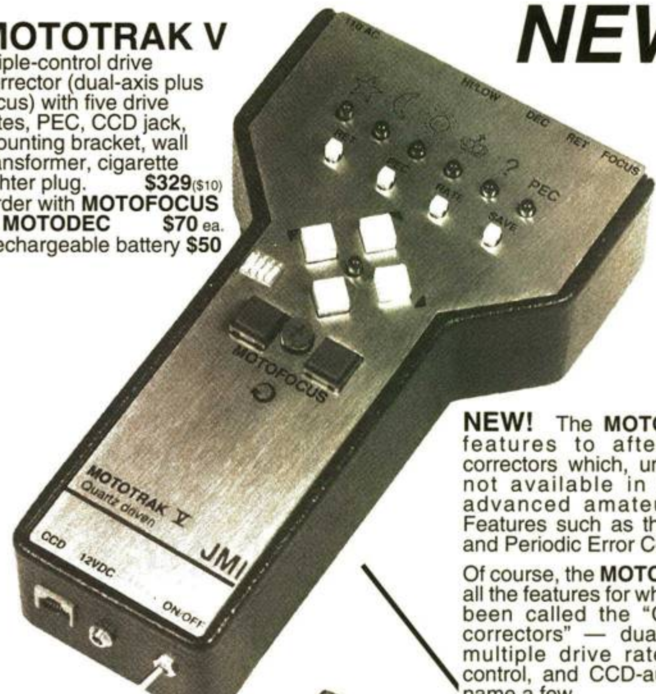

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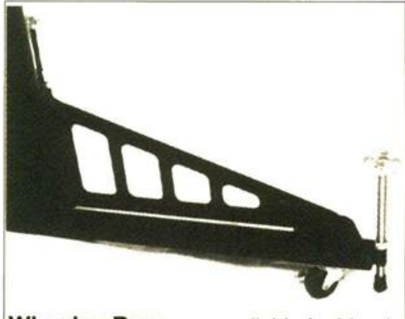

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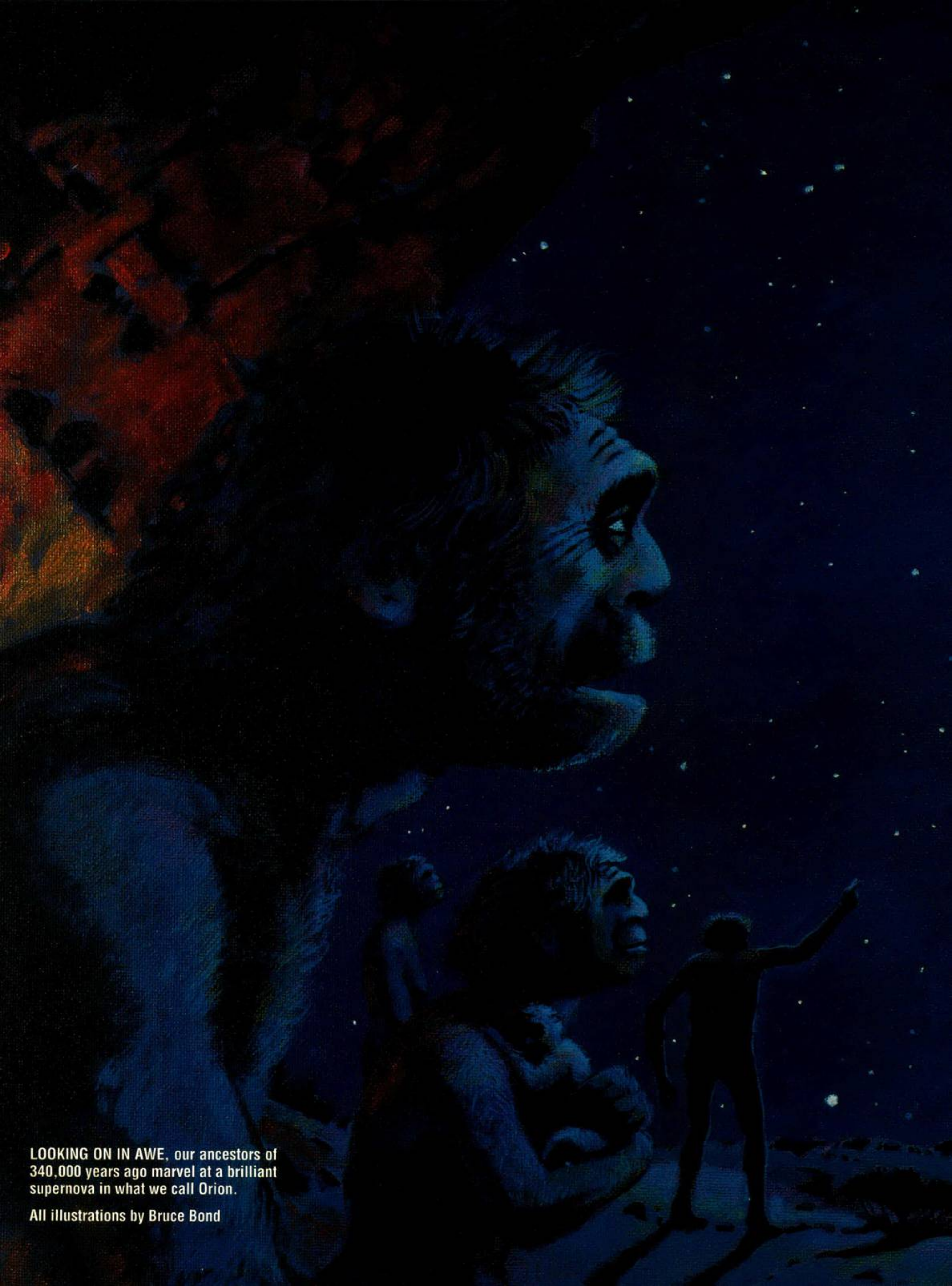

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All illustrations by Bruce Bond

The star that blew a hole in space

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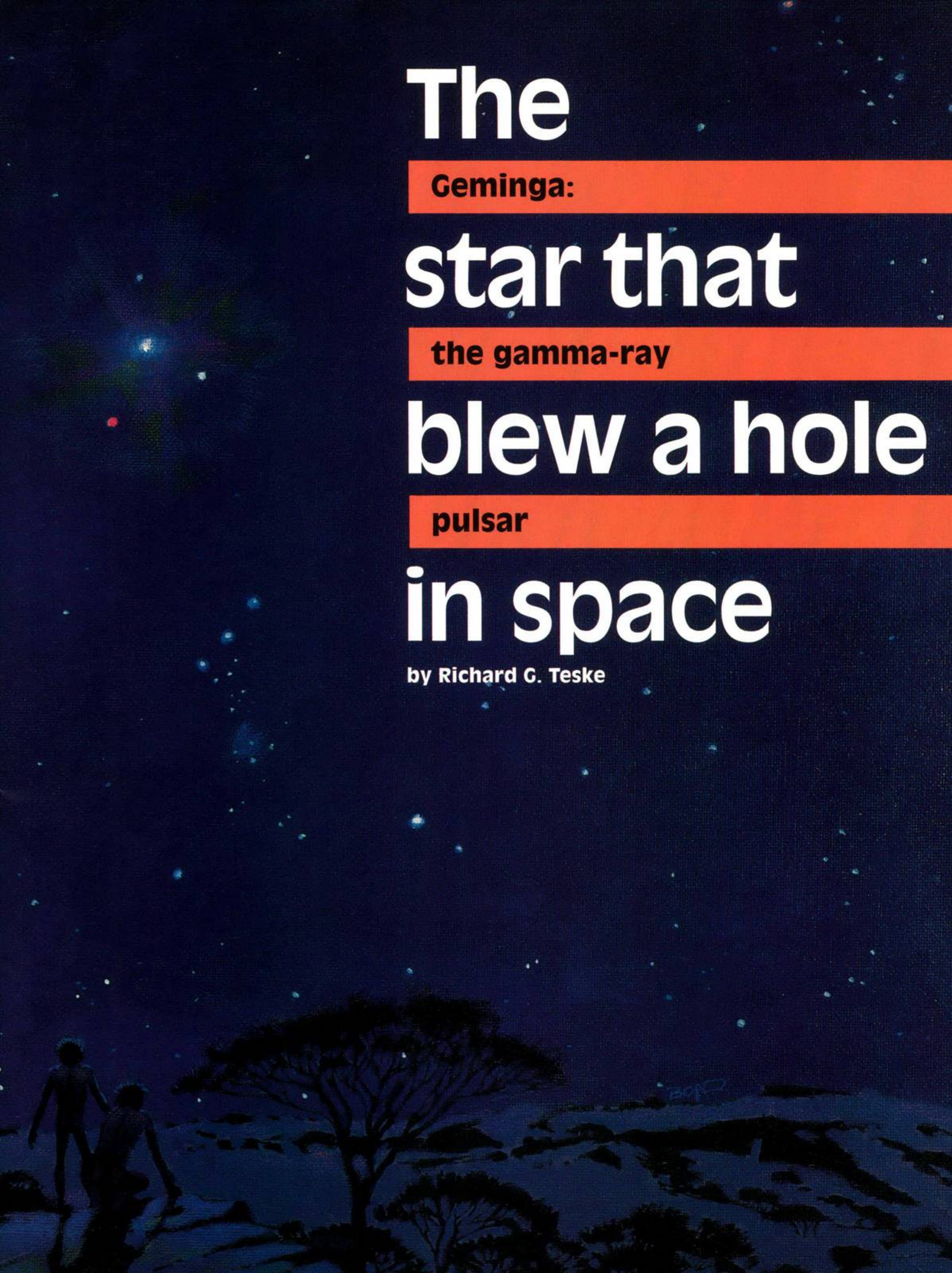
by Richard G. Teske



Some 340,000 years ago, a dazzling supernova appeared in the constellation we call Orion, between the bright stars Betelgeuse and Bellatrix. The star flared into such brilliance that it may have appeared brighter than the Full Moon. Even today, such a sight would amaze all but the most jaded inhabitants of our planet. Imagine then the puzzlement and wonder our primitive ancestors surely felt when confronted with this spectacle.

The supernova may have been 20 times brighter than the Full Moon and visible in daylight for more than two years.

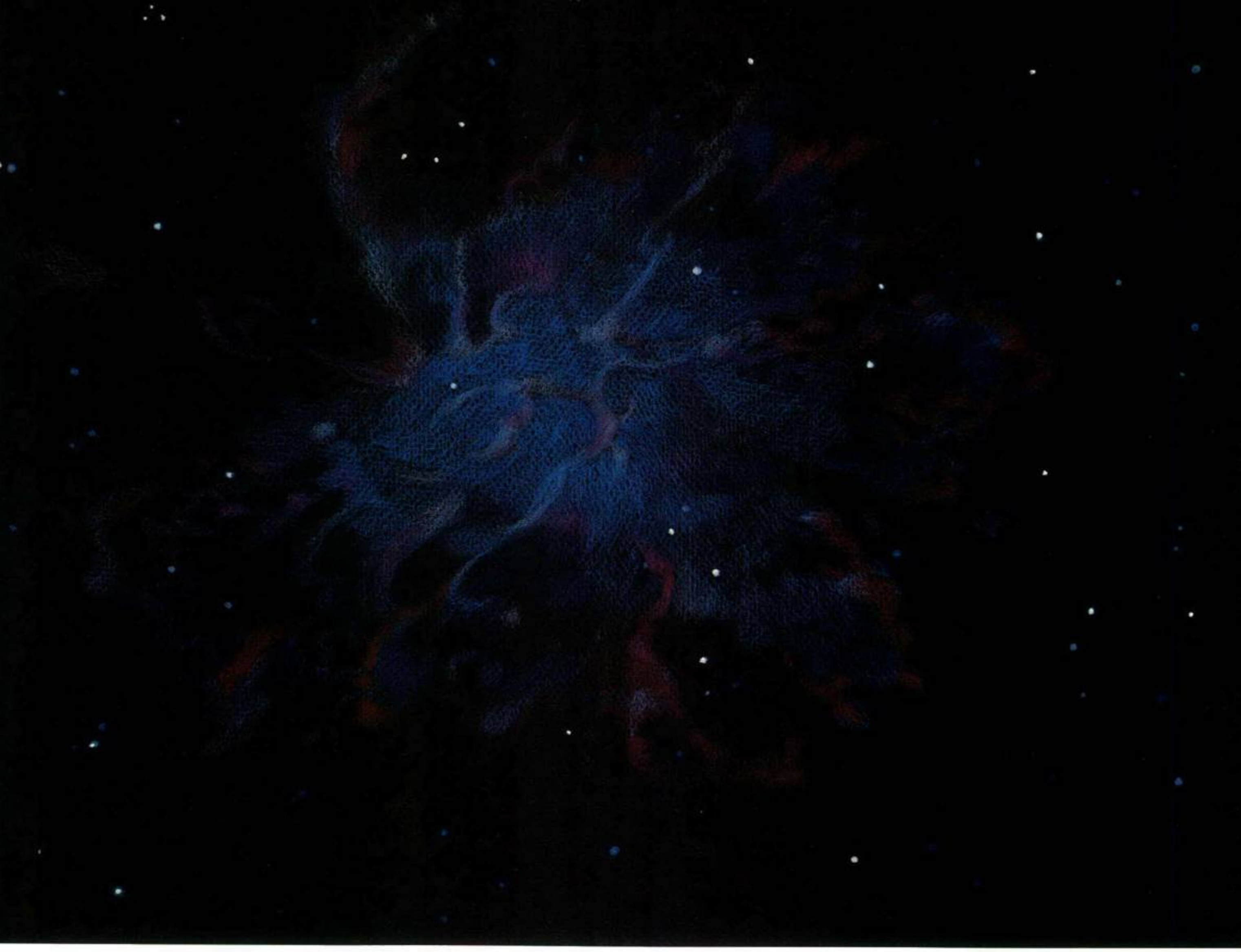
The prehistoric supernova could be seen in daylight for more than two years. Then it shone as brightly as its neighbors in the night sky for several more before gradually fading to invisibility. Thousands of years later, an expanding wall of searing gases created by the explosion rushed past the solar system, unnoticed by the descendants of those who had witnessed the supernova's appearance. This expanding shock wave may have excavated the Local Bubble, a vast, low-density region in the interstellar gas that the Sun and Earth now lie within. Far from Earth, the blast left behind a rapidly spinning neutron star — a pulsar — that remained hidden from view for hundreds of thousands of years more. Astronomers didn't discover the elusive pulsar until 20 years ago, when it became the first astronomical object ever revealed by its gamma-ray emission alone.

The pulsar created by the supernova blast was first detected in 1973 by NASA's second Small Astronomy Satellite, SAS-2. The satellite was looking for gamma rays, born when cosmic rays crash into the atoms and molecules of gas that spread thinly throughout interstellar space. In such a collision, the nucleus of the atom disintegrates, followed by the emission of a gamma ray. The gamma ray then shoots off in a random direction, perhaps one day to encounter an Earth-orbiting spacecraft. During its seven-month lifetime, SAS-2 detected some 8,000 gamma rays — about one every 40 minutes. Although most were from gas clouds in interstellar space, several hundred came from three starlike sources.

Two of the three were well-known pulsars: one in the southern constellation Vela and the other in the Crab Nebula, the remains of a supernova explosion witnessed on Earth in 1054. But the third starlike source, located in the constellation Gemini, couldn't be identified with anything visible at optical or radio wavelengths. For an object that was the second brightest gamma-ray source in the sky, this was truly perplexing. Because the other two gamma-ray sources were pulsars, the SAS-2 scientists suspected the unknown source was too. But repeated attempts to detect radio pulses from this area of sky proved unsuccessful and nothing unusual showed up with optical telescopes either.

SAS-2 looked at the enigmatic object for only a brief time, however, recording on average only one gamma ray every few minutes. Because pulsars typically pulse with periods of less than a second, the scientists couldn't tell if the observations showed signs of a pulse period. Officially the mysterious gamma-ray source entered the books listed by its galactic coordinates: 2CG 195+04. But the increasingly frustrated scientists began to call it Geminga, dubbed so by Italian astrophysicist Giovanni Bignami from a word in Milanese dialect meaning "does not exist" or "it's not there." The name Geminga also signified the object's location in Gemini.

Efforts to detect Geminga at other wavelengths finally succeeded in 1979 when NASA's Einstein X-ray telescope picked up X rays coming from it. The Einstein images gave a precise position for Geminga — locating it within six arcseconds on the sky, the size of a quarter seen from half a mile away. This provided the big break in the Case of the Elusive Pulsar. Armed with the new, precise position, astronomers again searched at radio and optical wavelengths. They still could find no radio emission, even with the 1,000-foot Arecibo radio telescope, the largest in the world. But large optical tele-



A THOUSAND YEARS AFTER THE BLAST, wispy tendrils of gas expand chaotically, spreading what were once the outer layers of the supernova's progenitor star into interstellar space.

scopes turned up three faint stars very close to the position determined by the Einstein telescope.

The 200-inch reflector on Palomar Mountain nailed down the dimmest of the three as Geminga. At magnitude 25.5, it was one of the faintest objects ever observed up until that time. It was so faint, in fact, that if its optical emission came in pulses the way the Crab pulsar's light did, we would not have seen it. To detect pulses of radiation and prove their conjecture that it was a pulsar, astronomers pinned their hopes on the upcoming flights of the Hubble Space Telescope and the joint German/American X-ray satellite called ROSAT.

In 1991 the ROSAT X-ray observatory peered toward Geminga for ten of its orbits of Earth; during those circuits the satellite logged the arrival times of 7,630 X rays, each to within 0.001 second. To see if the X rays arrived in pulses, Jules Halpern of Columbia University and Stephen Holt of NASA tested 262,144 different periods on the arrival time data. They concluded that Geminga did pulse with a period of 0.237097 second. At last an eighteen-year-long suspicion was verified: Geminga was indeed a pulsar.

When Halpern and Holt announced their discovery of the X-ray pulse period, a rumble of running scientific feet was heard as everybody with stored gamma-ray data from past space missions raced for their magnetic tape storage vaults. Now that the X-ray data showed the pulsar's period and the expected times when pulses would arrive, matching the old gamma-ray observations to the X-ray pulses was fairly easy. Almost immediately, re-examining observations from three earlier spacecraft

confirmed that Geminga also emitted gamma rays in pulses. The old data yielded crucial news: The pulsar's rotation is gradually slowing down. By combining the rate of slow-down with observations of the present rotation period and expectations of the rotation period at birth, astronomers estimated Geminga's age at around 340,000 years.

Although the pulsar has divulged its age, its precise distance from Earth remains elusive. But three lines of evidence inform astronomers that the pulsar lies nearby. First, the star appears to move across the sky quickly. Bignami and his colleagues determined this proper motion by measuring the pulsar's position on optical photographs taken several years apart. They found that Geminga's faint, shy spark is gliding northeast among the background stars at 0.17 arcsecond a year, covering the width of the Full Moon in approximately 10,000 years. Only the nearest stars have proper motions as speedy as this. (Undoubtedly the pulsar moves obliquely through space and is either partly coming toward us or partly moving away. But Geminga displays a continuous spectrum at optical wavelengths, so astronomers see no spectral lines that would reveal this component of its motion.) By tracing Geminga's proper motion backward in time, along with those of neighboring naked-eye stars, astronomers found Geminga lay halfway between and slightly above Betelgeuse and Bellatrix when it exploded.

A second piece of evidence for Geminga's proximity comes from its X rays. Interstellar gas atoms absorb X rays, but Geminga shows few signs of this absorption. These signs would be clear if it lay farther from us than 450 light-years.

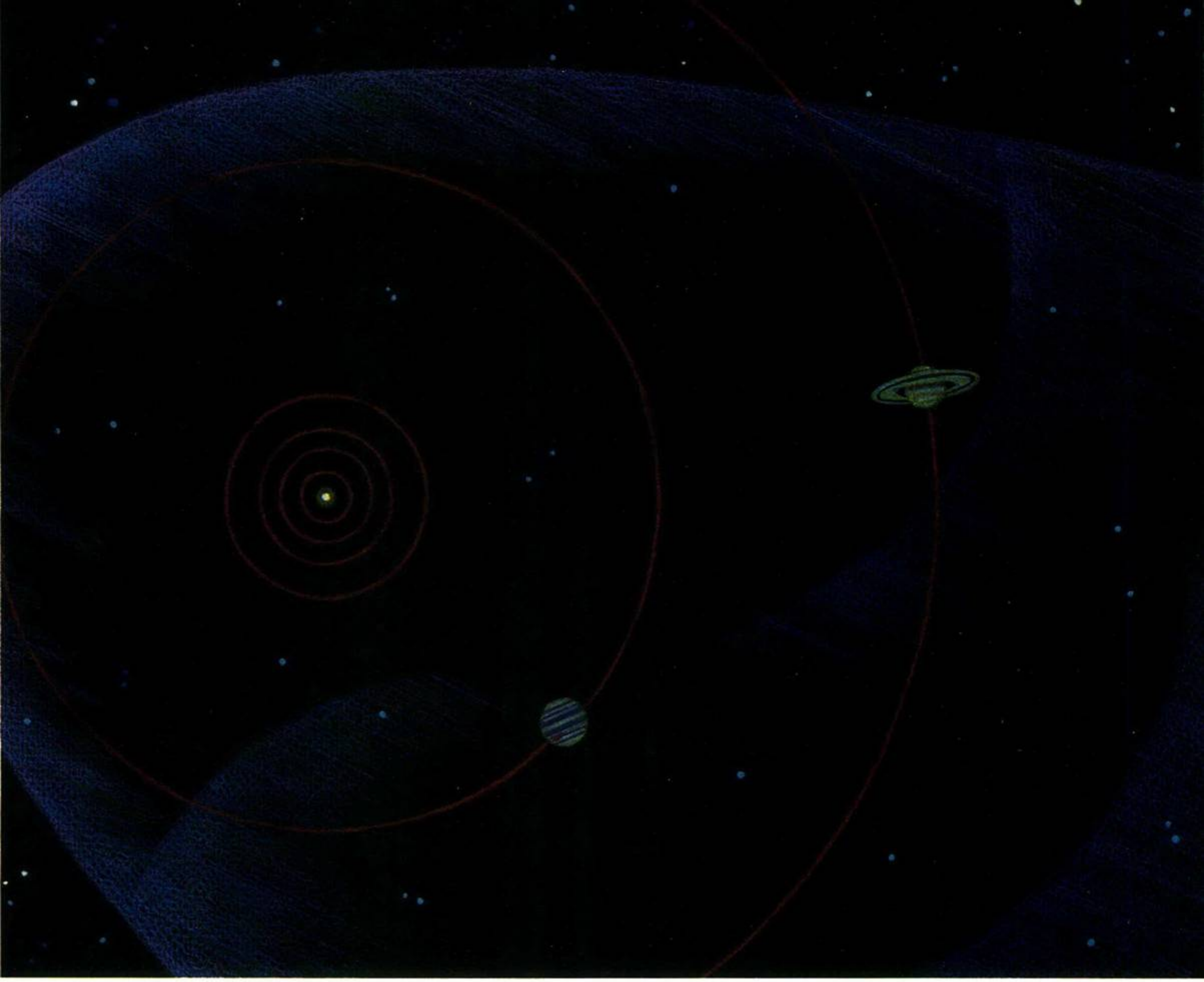
The third indicator is Geminga's gamma-ray brightness, which requires the pulsar to be within 1,300 light-years of Earth. Unfortunately none of this evidence gives the actual distance to the pulsar. But by putting all the information together, astronomers think Geminga now lies between 300 and 1,300 light-years away, and is more likely at the low end of that range.

If Geminga moves through space as fast as an average pulsar does, it could have traveled 150 to 300 light-years from the site of its explosion. That places the supernova nearby, perhaps even closer than 100 light-years away. By finding the pulsar's distance and its three-dimensional motion, astronomers hope to learn just where the progenitor star was when the supernova cataclysm overtook it.

While Geminga provides limits on how distant the supernova may have been, Earth sets the limit on how close the supernova could have been. A nearby blast would have left indelible marks on Earth, marks that scientists have not found. Take for example a possible flash of X rays and gamma rays generated by the supernova. Fortunately Earth's upper atmosphere would absorb this high-energy radiation, protecting the inhabitants below. But suppose the supernova was only one light-year away. The energy absorbed by the atmosphere then would be enough to strip off all the layers above 50 kilometers altitude. There's no evidence that this happened, so the Geminga detonation must have been farther away than a light-year.

But a flash of energetic radiation could still severely affect Earth's atmosphere even if the supernova occurred farther from the solar system. Malcolm Ruderman of Columbia University pointed out years ago that when the upper atmosphere absorbs X rays and gamma rays, they start chemical reactions that destroy ozone in the layer that protects us from the Sun's ultraviolet rays. Ruderman thinks a supernova blast nearer than 30 light-years away could deplete much of Earth's ozone layer for as long as several years. As a result terrestrial life might be significantly harmed, not by the supernova emissions themselves — they would be absorbed in the upper atmosphere — but by solar ultraviolet light later on. Ruderman found nothing in the biological record to indicate such a catastrophe occurred around 340,000

An expanding wall of searing gases rushed past the solar system, engulfing the outer planets and their satellites.



SOME 9,000 YEARS AFTER THE EXPLOSION, the supernova's blast wave slams into the solar system, pushing the solar wind's sphere of influence inside the orbit of Saturn.

years ago, which affirms that the supernova must have been farther away than 30 light-years.

Perhaps our best hope for pinning down the supernova's distance is by investigating the "smoking gun" (actually it's a "smoking bomb") — the link between Geminga and the Local Bubble. The evidence literally surrounds us. Astrophysicists have long known that the solar system lies inside a hot, rarefied cavity, or bubble, in the interstellar gas. About seven years ago, Don Cox and Ron Reynolds of the University of Wisconsin advanced the idea that the Local Bubble resulted from a supernova blast within the last several hundred thousand years. Their reckoning tallies surprisingly well with the estimated age of the Geminga pulsar.

Creating a rarefied bubble in the interstellar gas begins when a supernova hurls a dozen or more solar masses of star-stuff into space. This paper "flies" off the firecracker at speeds up to 60,000 kilometers per second. What had been the outer layers of the star are ejected with the greatest speeds; layers that were part of the interior leave later, are thrown outward a bit more slowly, and tend to lag behind. At first the star's wreckage expands freely into its surroundings, heading out into interstellar space and plowing up any material around the shattered star. In a hundred years or less, it sweeps up enough surrounding interstellar gas that the debris begins to slow down. However, the shock wave continues on into the interstellar gas, sweeping it up, heating it to temperatures of a million degrees, and pushing it outward.

Meanwhile, the layers ejected from the star's interior catch up with the slowing outer layers, colliding violently with them. Most of the gas becomes jammed up in a single, expanding shell. As a result, the supernova cavity resembles a growing soccer ball. Almost all the material is in the skin, which is a hodgepodge of the star's outer and inner layers, chemical elements cooked up during the blast, and the heated, swept-up interstellar gas. By contrast, the cavity's interior contains very little material — the supernova has blown a hole in space that can last for a million years.

> **The shock wave from the Geminga supernova blast may have excavated the Local Bubble in galactic space.**

Observations made with spacecraft reveal that the Local Bubble is pear-shaped, with its long dimension directed up and down out of the Galaxy's central plane. At its narrowest, the bubble stretches about 200 light-years across. It is fattest on the north side of the Galaxy, where it has a width of about 600 or 700 light-years and reaches a similar distance above the Galaxy's plane. South of the plane, the bubble extends roughly 300 light-years. Astrophysicists explain the bubble's odd shape by pointing out that the interstellar gas is most dense in the galactic plane and becomes more rarefied above and below it. Thus the bubble has had an easier time expanding above and below the plane than it has pushing its way outward in the plane.

NASA's Neil Gehrels and Wan Chen place the Local Bubble's center less than 200 light-years from us, in the direction of the constellation Orion, which is remarkably close to where astronomers think the Geminga supernova occurred. They conclude if the supernova went off at what is now the Local Bubble's center, it was less than 200 light-years distant.

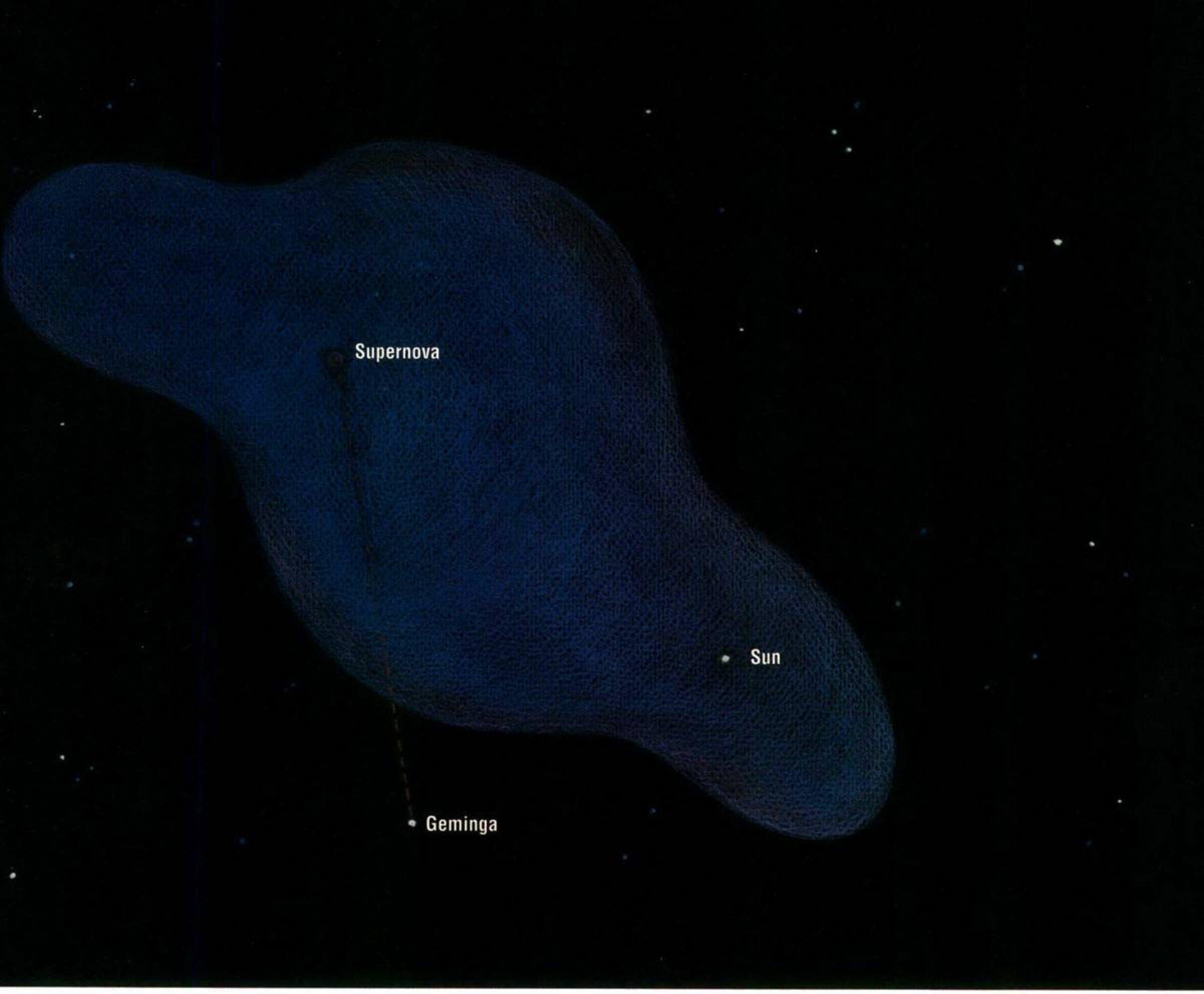
The same shock wave that excavated the Local Bubble must have created spectacular events when it rushed by the solar system. While the million-degree wall of onrushing gas probably did not touch Earth and the other inner planets, the outer planets and their satellites may have been bathed in it. The key lies in how the material interacted with the solar wind, which normally shields the Sun's family of planets from interstellar space.

The rarefied solar wind is a stream of charged particles consisting mostly of protons and electrons that flows from the Sun at speeds around 500 kilometers per second. As it heads toward interstellar space, the wind's pressure drops slowly. Finally, at a distance where its pressure is just balanced by the pressure of the interstellar material, the flow and its influence halt. Astronomers think that happens at about 150 astronomical units from the Sun, well beyond the planetary orbits.

Although the solar wind allows cosmic rays and some neutral atoms to penetrate into the inner solar system, it's strong enough to keep most of the interstellar material well away from us. But the solar wind is no match for the shock wave from a nearby supernova.

Gas pressure behind the advancing shock wave is so much higher than that normally found in the interstellar medium that the shock wave will buffet and squeeze the solar wind into a much smaller region around the Sun. Although the inner planets would still be isolated and protected from the blast wave's fury, the outer ones, together with their satellites, would be laid bare and subjected to the full effects.

To learn which planets would be exposed to the scorching material behind the shock wave, we need to know the distance of the blast. Let's suppose the Geminga supernova exploded 100 light-years from the Sun. (Gehrels and Chen say less than 200, while Ruderman calculates more than 30.) At 100 light-years, the supernova would be 20 times brighter (at a magnitude of about –16) than the Full Moon. Nine thousand years later the shock wave would arrive, having slowed to "merely" 1,400 kilometers per second by that time. Once the solar system was engulfed by the withering gust, the solar wind's influence would stop at about the orbit of Jupiter. So Saturn, the outer planets, and



THE LOCAL BUBBLE WE SEE TODAY is a huge, hollowed out volume of space possibly created by the supernova that gave birth to Geminga.

their satellites would be exposed to the onrushing debris.

Only if the blast happened closer to us than 30 light-years would the solar wind boundary be pushed far enough toward the Sun to imperil Earth. But even if the detonation was as far away as 200 light-years, calculations show that Uranus, Neptune, and Pluto would be uncloaked by the solar wind. So it's likely that some of the outer planets took a hit from the blast wave not all that long ago, astronomically speaking.

The blast wave would have brought the chemical elements created in the Geminga supernova and those swept up by the advancing shock wave and emplaced them upon the airless outer moons. The surfaces of these moons have remained virtually unchanged after approximately 340,000 years, so looking for recent supernova debris on them might succeed. Future space missions to the outer solar system may include a search for these chemical elements.

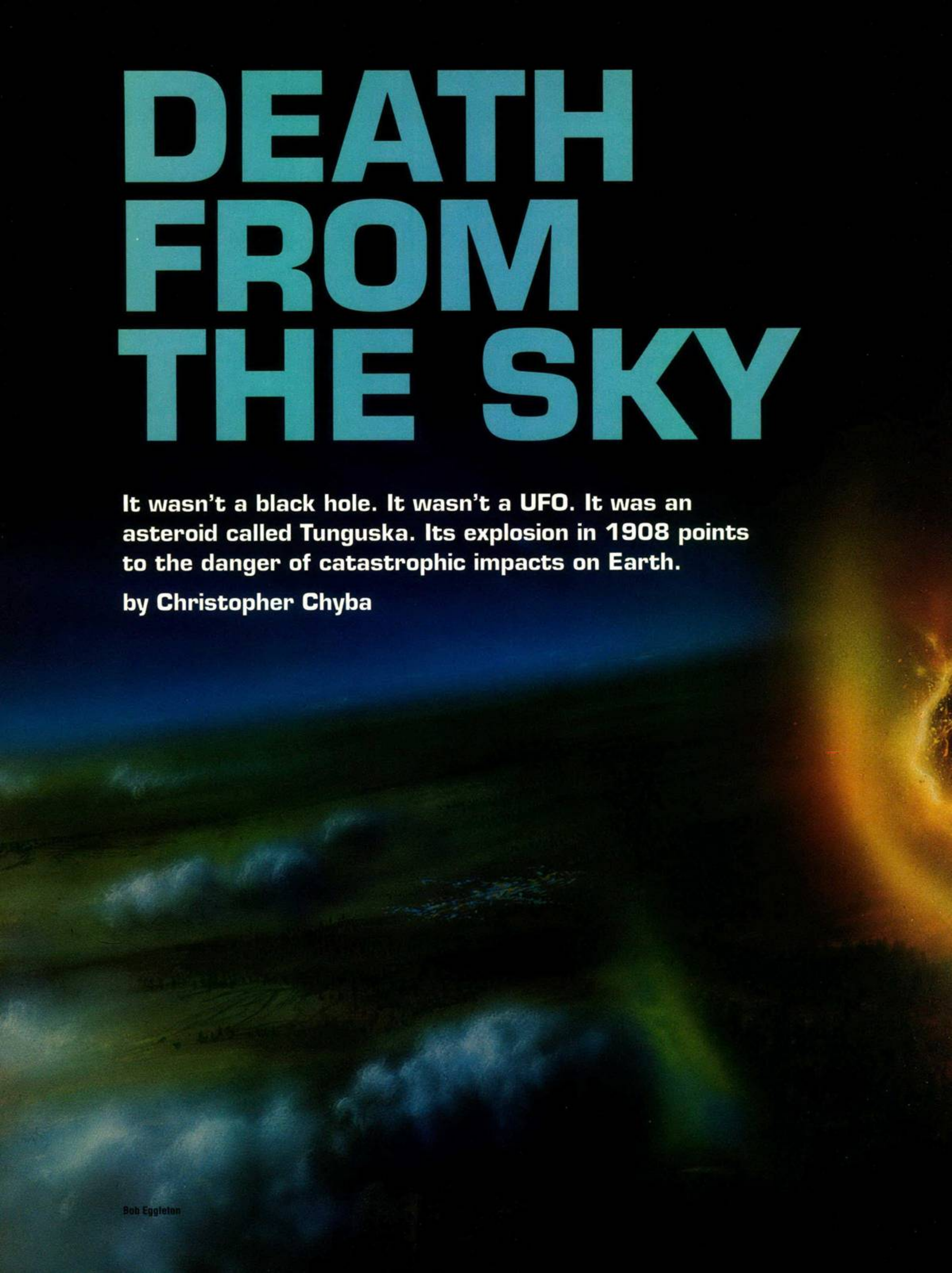
Twenty years ago, Geminga was just a glimmer in astronomers' eyes, a source of gamma rays so mysterious it was named "Does-not-exist." During the past two decades, Geminga has come into focus as a pulsar created in a nearby supernova explosion. Now astronomers are working feverishly to measure its distance and to see how the supernova relates to the Local Bubble. Only then will the Case of the Elusive Pulsar be solved, ending a mystery begun 340,000 years ago. ☐

Richard G. Teske is a retired professor of astronomy at the University of Michigan in Ann Arbor.

DEATH FROM THE SKY

It wasn't a black hole. It wasn't a UFO. It was an asteroid called Tunguska. Its explosion in 1908 points to the danger of catastrophic impacts on Earth.

by Christopher Chyba



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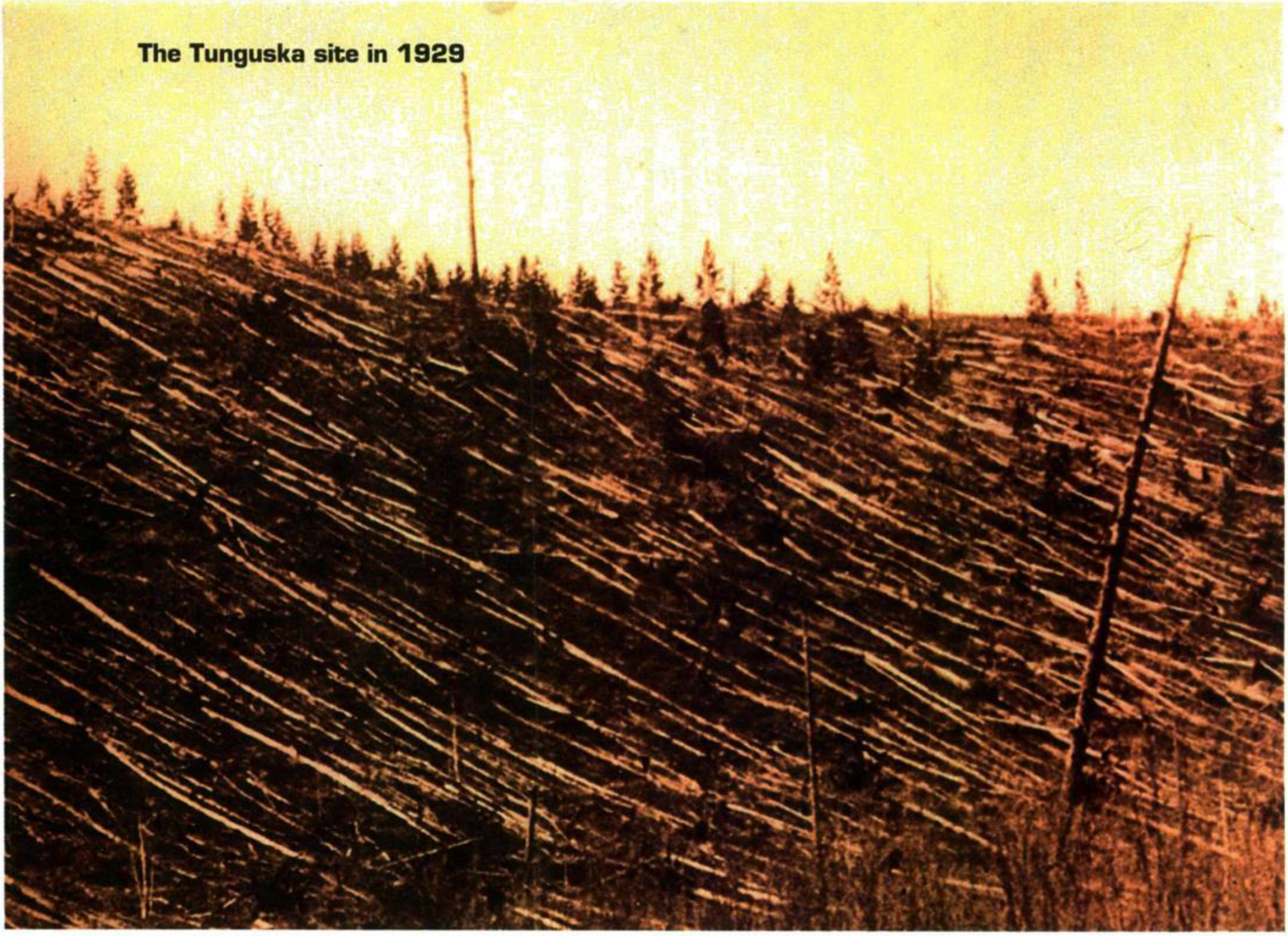


The Tunguska site in 1929

Leonid Kulik

One summer day in 1908 a little piece of central Siberia vanished. In the midst of a powerful explosion in the atmosphere, over 2,000 square kilometers of forest were suddenly flattened. The explosion snapped trees like matchsticks and devastated wildlife. Ever since, the Tunguska explosion has fascinated scientists and the popular imagination. Long thought to be the result of a glancing blow from an asteroid or another body from the solar system, the Tunguska event is finally getting the critical analysis it deserves.

Eighty-five years after the fact, the Tunguska impact is taking on more significance because understanding it tells scientists about other impacts on Earth, past, present, and future. Will such an impact happen again? Astronomers using the Spacewatch telescope on Kitt Peak near Tucson have begun compiling a catalog of small asteroids whose orbits cross Earth's. Their findings over the past two years have been extraordinary. First, small Earth-crossers — objects smaller than 50 meters in diameter, half the size of a football field — pass close to Earth 10 to 100 times more frequently than scientists previously believed. Second, many of the small Earth-crossers have orbits similar to Earth's. Earth is slowly sweeping up these asteroids in collision after collision.

How much destructive energy do these asteroids have? Quite a bit, it turns out. One of the smallest Spacewatch objects, designated 1991 BA, measures about 10 meters or less in diameter. Yet if 1991 BA struck Earth, the resulting explosion would likely exceed the energy released by either of the atomic weapons exploded over Hiroshima and Nagasaki at the end of the Second World War, each about 20 kilotons of TNT. But we don't need to use nuclear analogies to get a sense of what such an explosion would be like. Our own century has already provided us with several examples.

Revelstoke

Early on the clear night of March 31, 1965, thousands of people in British Columbia and Alberta saw the explosion of a large meteor about 30 km up, somewhere above the town of Revelstoke, 280 km west of Calgary. Canadians heard a detonation as far as 200 km away. An Air Canada pilot reported the event from 800 km away while flying westward over Saskatchewan. Scientists recorded atmospheric pressure waves caused by the blast in Boulder, Colorado. Researchers later analyzed the recordings and found the blast had an energy of about 20 kilotons, about equal to the Nagasaki bomb in 1945.

Yet no one on the ground near Revelstoke was injured, no trees were toppled, and no crater was found. For that matter, despite searches by helicopter and plane, no one found any meteorite fragments, either.

About two weeks later, Canadians Elmer Coats and Alfred Daniels were busily snowshoeing over six feet of powder, heading north from Seymour Arm, an isolated settlement at the top of Shuswap Lake in British Columbia. The men were trapping beavers, working their way to Macpherson Lake, about 10 km away. Scientists had already combed the nearby Monashee Mountains by snowshoe and helicopter, looking without success for evidence of an explosion, and a reconnaissance plane had also turned up nothing.

Then Coats and Daniels happened onto an area of darkened snow on the surface of Macpherson Lake. Suspecting they had found something linked to the explosion, the two beaver trappers behaved just as trained scientists would. At one end of the darkened snow they could see millimeter-sized particles buried deep within the lake ice. They found two such patches of particles and dug down and recovered as much as they could of the first one. They left the other untouched to provide a pristine site for possible later research by a scientific team. When the explorers found a second, similar site about a kilometer away, they treated it the same way. Analysis of the recovered samples, which all together weighed less than one gram, revealed that the Revelstoke object was a carbonaceous chondrite, the most primitive and fragile of meteorite types known. Subsequent searches by helicopter in July and August failed to find more material. Whatever other dust had been deposited was lost as the ice and snow melted.

Had Coats and Daniels not reached the site of the meteorite fall until after the snows had melted, no trace of the Revelstoke object would ever have been found. A 20-kiloton explosion would have occurred, been witnessed by thousands, and left no visible trace. Perhaps in this case the press would even today speculate on the identity of the mysterious Revelstoke object. The supermarket tabloid headlines might read "Revelstoke! Black hole, antimatter, or UFO?"

From Revelstoke to Tunguska

The 1908 explosion over the Tunguska River in central Siberia was closer to the ground and much more powerful than Revelstoke. It released about 1,000 times more energy. Fortunately, the area was sparsely populated. A number of Tungus reindeer herders were thrown to the ground and some tents and cabins were damaged, but as far as we know, no one was killed. No crater was ever found, and no one picked up any meteorite fragments.

The atmospheric shock wave from the explosion circled Earth twice and was recorded on instruments as far away as England. The instruments used to record these pressure waves were predecessors to those used later in the century to estimate the strengths of atomic weapons tests in the atmosphere, so the data can be interpreted in an analogous way. Scientists also captured seismic readings of the ground tremors caused by the explosion. The best estimates we have for the blast energy and altitude of the Tunguska event come from these data.

However, we can also calculate the blast characteristics from the physical evidence on the ground. The explosion created a distinct pattern of treefall around Tunguska, spread over an irregularly shaped area of 40 by 45 km. Soviet expedition members later measured the orientations of some 40,000 fallen trees. All of the toppled trees pointed away from a central location that must have been directly below the point of the explosion. Interpreting the extent and orientation of the treefall pattern, scientists concluded the explosion at Tunguska likely released 10 to 20 megatons of energy somewhere around 8 km above Earth's surface. This agrees nicely with the characteristics predicted by the atmospheric pressure and seismic records.

But at the time of the Tunguska event no one made a connection between the atmospheric shock waves and the Siberian explosion. No one correctly interpreted the "light nights" that followed over Western Europe during which sunlight reflected off high-altitude clouds and dust created by the explosion. Outside the local region in Siberia, the Tunguska explosion remained nearly unknown for more than a decade. In the interim, Russia was wracked by world war and revolution. Tunguska could have seemed mild by comparison.

"I cannot sort out my chaotic impressions."

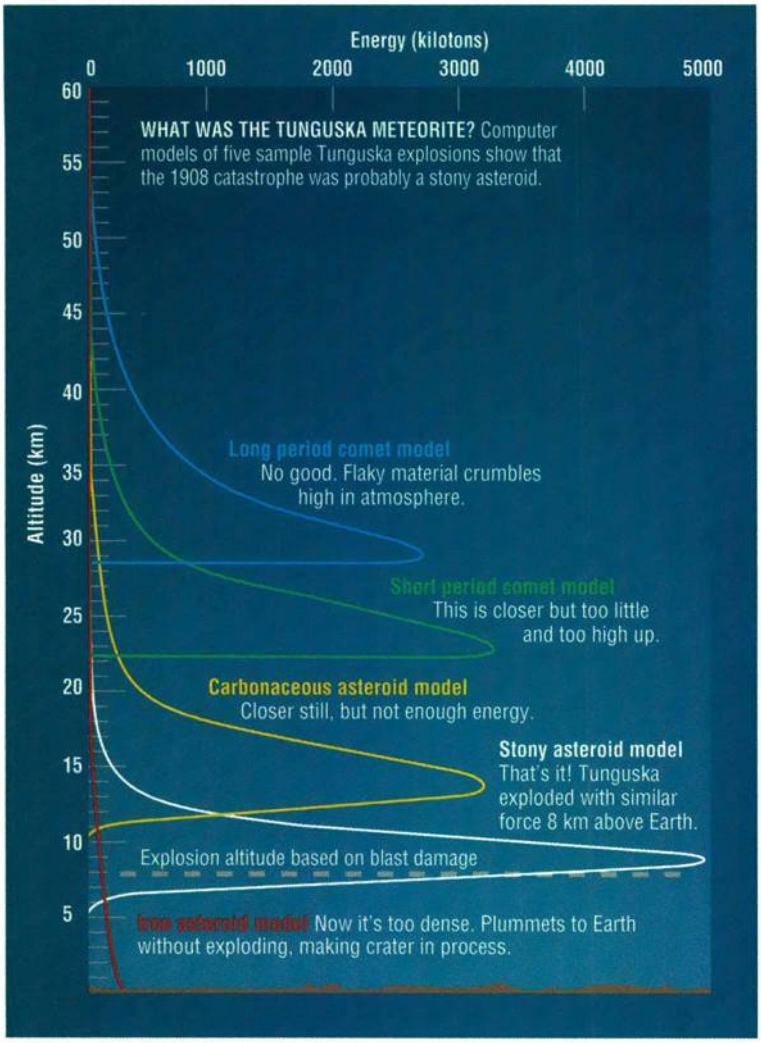
Leonid A. Kulik, a researcher from the Mineralogical Museum of the Russian Academy of Sciences, was the first scientist to reach the site of the Tunguska devastation. In 1921 the academy equipped the country's first systematic meteorite expedition, led by Kulik, to investigate the sites of many supposed meteorite falls. Before leaving on the expedition Kulik by chance saw a page torn from a 1910 St. Petersburg calendar. The back of this sheet contained part of an article from a 1908 issue of *Siberian Life*. The article included eyewitness reports of the fall of a great meteorite somewhere near the Tunguska River. Kulik investigated and found that a number of Siberian newspapers contained stories about the fall. Some of them were embellished with fantastic details, and some contradicted others. But something impressive had happened and so in September 1921 Kulik set out by rail to the region of the Tunguska River.

Kulik's party was ill-prepared for the extensive exploration required to find the exact location of the Tunguska fall, which lay some 700 km north of the nearest rail line. They didn't attempt it. But Kulik did collect reports from witnesses to the event and distributed questionnaires. He convinced himself that a great explosion of some kind had taken place. Of course Kulik gathered these first reports more than 13 years after the event, and he collected additional reports throughout the twenties. On the basis of this evidence, in 1927 the Soviet Academy of Sciences authorized Kulik to lead the first expedition to the Tunguska site.

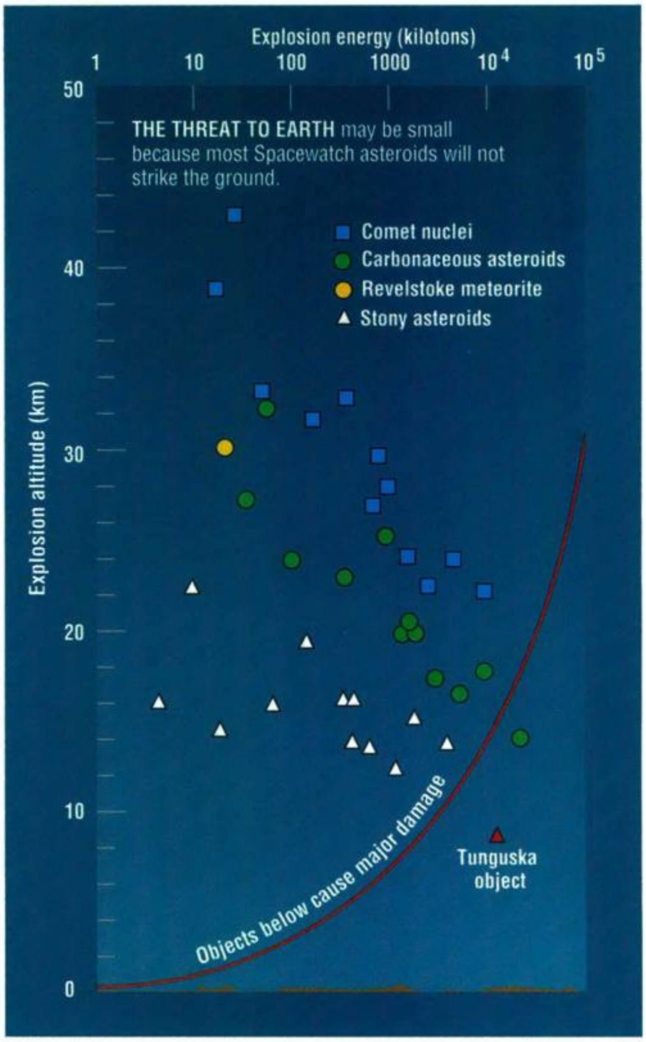
Russia's Tunguska explosion flattened hundreds of thousands of trees and was recorded on primitive instruments as far away as England. What caused such a spontaneous blast?

In February 1927 Kulik and an assistant set out from Leningrad. By April, with the help of a Tungus guide named Il'ya Potapovich, they reached the southern boundary of the region of devastated forest. Kulik recorded the scene in his diary.

I still cannot sort out my chaotic impressions of this excursion. In the north the distant hills along the River Khushmo are covered with a white shroud of snow half a meter thick. From our observation point no sign of forest can be seen, for everything has been devastated and burned, and around the edge of this dead area the young twenty-year-old forest growth has moved forward furiously, seeking sunshine and life. One has an uncanny feeling when one sees 20-30 inch thick giant trees snapped across like twigs, and their tops hurled many meters away to the south.



WHAT WAS THE TUNGUSKA METEORITE? Computer models of five sample Tunguska explosions show that the 1908 catastrophe was probably a stony asteroid.



THE THREAT TO EARTH may be small because most Spacewatch asteroids will not strike the ground.

By June, Kulik had found the epicenter of the destruction. The journey through the forest wasteland had not been without peril:

> *In the early part of the day when the wind rose, it was very dangerous to walk through the old dead forest; twenty-year-old dead giants rotted at the roots were falling down on all sides. Sometimes they fell quite close to us. As we went along we kept our eyes on the tree-tops so that, if they fell, we should have time to jump aside.*

Some trees had been stripped of their branches, scorched, and killed where they stood, and many others had been uprooted or snapped clean. Kulik discovered that the trees that had been toppled or snapped all pointed away from one central area, which he named the "cauldron." The interpretation was clear. The Tunguska meteorite had exploded above this central point and the blast had blown the forest outward in all directions.

The Tunguska meteorite must have been a stony asteroid that exploded with 15 megatons of force 8 km above Earth.

After these discoveries Kulik had little trouble getting support for subsequent expeditions. He led another in 1928 and another in 1929-30, this time wintering over at the site. Expeditions continued throughout the thirties. But despite some false alarms, no craters or meteorite fragments were located. Kulik died in 1942 after being taken prisoner by the German army in World War II.

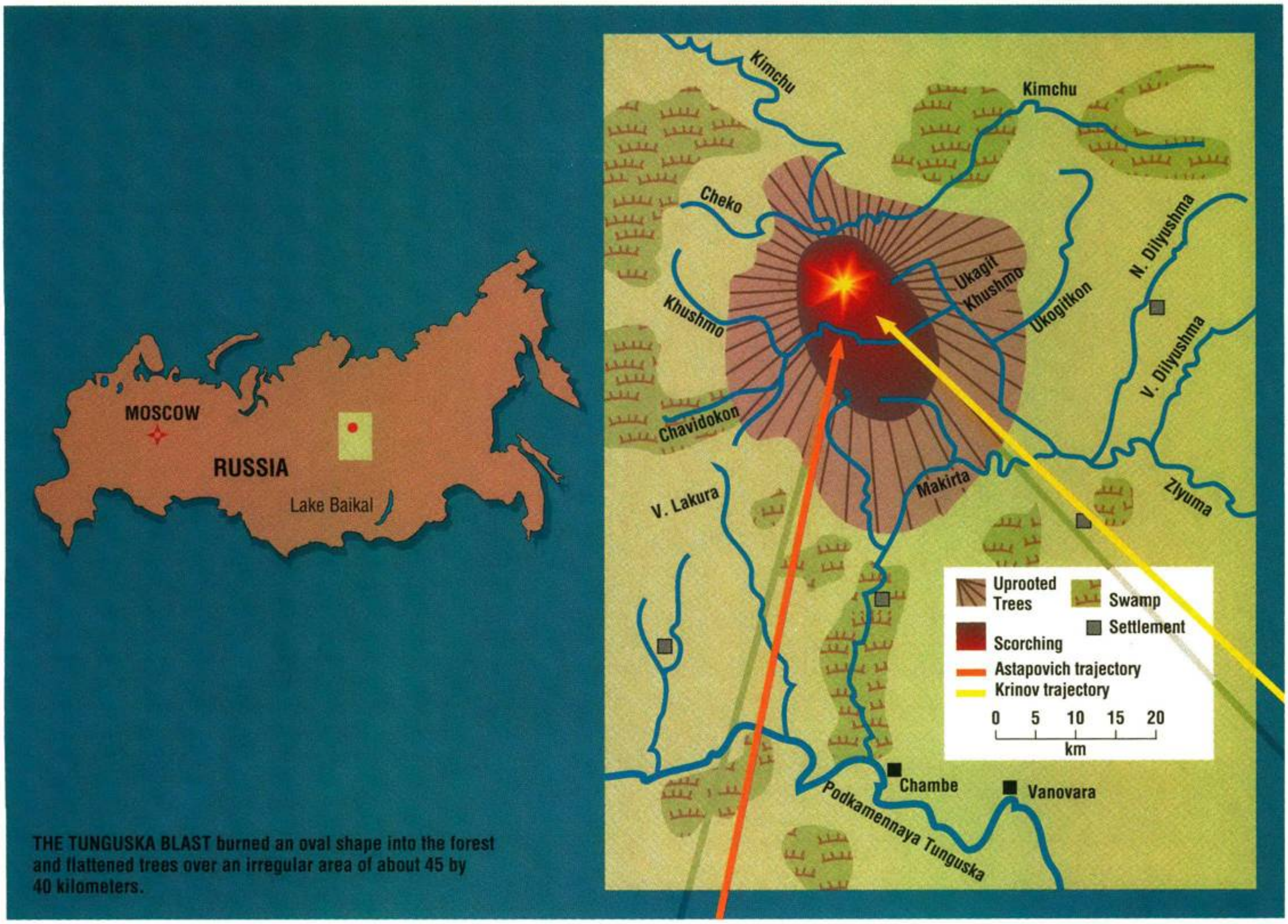
Black Hole, Antimatter, or UFO?

Kulik's on-site research leaves us with a disappointingly incomplete picture of the Tunguska event. That has troubled scientists throughout the past few decades. Not long ago, with a colleague, I gave a lecture about the Tunguska event. My colleague made the posters for our talk, secretly titling them "Black Hole, Antimatter, or UFO?" and then put my name first. The room filled to overflowing — and my colleague failed to show up until well into the talk.

His practical joke worked because of the bizarre explanations the Tunguska event has attracted over the years. Tunguska's area of destruction is larger than the area of New York City. So much devastation and yet no crater. And if this peculiar scenario was caused by an infalling meteorite, why should the interloper explode in the atmosphere before hitting the ground?

Apart from the Loch Ness Monster and Bigfoot, virtually every scientific or pseudoscientific explanation has been tried on the Tunguska fall. What these hypotheses lack is testability. Any acceptable scientific explanation of the Tunguska explosion has to make use of phenomena that we know something about. This is so astronomers can make consistency checks and see if the explanation stands up to the tests. If it's not testable, it's not a scientific explanation. Some have suggested that a "mini" black hole collided with Earth, passed through it and left no crater. Why the black hole left no sign has never been explained.

What about antimatter? It would take only a tiny



THE TUNGUSKA BLAST burned an oval shape into the forest and flattened trees over an irregular area of about 45 by 40 kilometers.

ASTRONOMY: Phil Kirchmeier, after Christopher Chyba

meteorite made of antimatter to produce a 20 megaton explosion. But besides the fact that astronomers have never observed any signs of antimatter meteorites, a grave objection to this hypothesis traces all the way back to 1949. In his book *The Face of the Moon*, Ralph Baldwin showed that an antimatter meteorite massive enough to penetrate as deeply into the atmosphere as the Tunguska object would generate more than ten thousand times the energy of the actual explosion.

Of course, when all else fails people call out the flying saucers. In one sense this solution to the Tunguska mystery works very well — it has to. An advocate of flying saucers can always endow the supposed alien spaceship with exactly the characteristics necessary to explain the event. Of course this isn't an explanation in the scientific sense.

Another possible explanation for the Tunguska explosion does meet the criterion of testability. Could the explosion have been caused by methane, or swamp gas? This idea can be tested. Scientists know how much energy a cubic foot of methane gas produces if it ignites with 100 percent efficiency. How much methane would have had to accumulate at the Tunguska site to have caused the explosion, assuming perfect combustion? It's a simple calculation. You would need 60 billion cubic feet of pure methane gas. Saudi Arabia produces about this much natural gas in one month. I think it strains credibility to imagine this much methane accumulating above the Tunguska swamps and then somehow generating a point-like explosion.

Enter the Asteroid

But what about Kulik's original idea, that the explosion was caused by a meteorite? Perhaps it was a small comet, or perhaps a small asteroid, but in any case some cosmic body must have exploded in the atmosphere. It's not hard to estimate how large this body must have been, from the energy it released. We know how fast typical Earth-crossing asteroids or comets are moving when they hit Earth, about 40 to 60 km/sec. From this, it's easy to estimate that the Tunguska object must have been about 60 meters across — a bit more than half the size of a football field. The question with the Tunguska event has always been how to convert this kinetic energy of motion into explosive energy before the object hits the ground and makes a crater.

But the Tunguska mystery goes beyond the lack of a crater. In addition, no significant pieces of the object were ever found. This objection might seem strong if not for the Revelstoke explosion. Revelstoke was a thousand times smaller than Tunguska, scientists were able to recover little more than a gram of dust at Revelstoke. If a few more months had passed nothing would have been left. So what would the chances be of finding significant amounts of Tunguska dust more than ten years after the explosion, after the snow had fallen and melted more than ten times, and the runoff had sunk into the Tunguska River? Even though the Tunguska explosion was much larger, the chances weren't good. The few submillimeter-sized metallic spheres collected by Kulik at the Tunguska site underwent analysis in the 1980s. These particles contain certain key elements in cosmic proportions, amounts characteristic of meteorites and very different from those on Earth. These spheres probably formed out of material from the object that recondensed like metallic raindrops after first being vaporized in the explosion.

Tunguska Was Mundane

Over the past decade or so investigators have come to realize that it is not extraordinary that a chunk of rock or ice the size of a football field explodes in midair and hurtles to the ground. The Tunguska explosion is now considered typical for a small comet or asteroid entering Earth's atmosphere at a typical velocity. Despite the dramatic appearance, the Revelstoke and Tunguska explosions were anything but extraordinary — they were mundane. Many Tunguskas and Revelstokes have occurred, and many such explosions will take place in the future. From our knowledge of Tunguska and Revelstoke we can picture what this type of event must be like.

Imagine a football-field-sized asteroid in an Earth-crossing orbit. Suppose Earth happens to be in the wrong place at the wrong time and its gravity scoops up this rogue body. If the asteroid were typical, it would then enter our atmosphere with a velocity of around 15 km per second — about 34,000 miles per hour. Because the asteroid is moving so fast, the atmosphere doesn't have time to flow or be pushed out of the way. Instead, the air gets compressed and piles up in front of the body. Meanwhile, behind the asteroid, the atmosphere is a near-vacuum because the air hasn't had a chance to rush back in. An enormous pressure difference builds up across the asteroid — huge pressure in front and nearly no pressure behind — and gets bigger and bigger as the asteroid moves deeper into the atmosphere.

Atmospheric explosions like Tunguska are ordinary events, even though we rarely witness them.

What happens next depends on what the asteroid is made of. If the asteroid is strong enough, say made of iron with a few cracks or lines of weakness, perhaps nothing happens until the asteroid hits the ground. An iron object with the energy of the Tunguska body produced Meteor Crater in Arizona some 50,000 years ago. Despite the enormous atmospheric pressures on this object, the Meteor Crater projectile was strong enough to withstand them.

But that's iron. What if the object is weaker? Suppose it's made of rock. In this case the pressure difference across the object will eventually exceed the object's strength. Once the rock can no longer support itself against this pressure, it will crumble and begin to "pancake." Caught in the vise of the high pressure ahead and low pressure behind (caused by its own velocity), the rock has no choice but to flatten sideways. And then, very quickly, the game is over. Once the rock begins to spread, its surface area goes up, and atmospheric drag increases, slowing the object. It spreads even more, and the density of the atmosphere all the while increases exponentially as the object nears the ground, creating more drag. These overwhelming forces together stop the fragmented object abruptly in the atmosphere, exploding it like a bomb.

Detailed computer models show that the disintegration and explosion happen in one or two tenths of a second. In the case of Tunguska, within a fraction of a second 15 megatons of kinetic energy were lost as the object stopped cold 8 km up. But energy is conserved, and those 15 megatons had to go somewhere. These 15 megatons converted into high temperatures and high pressures. The rock vaporized! A shock wave raced outward. The underlying forest was sequentially set alight, snuffed, and toppled as the heat and the shock wave raced past.

Interlopers made of different materials will in fact explode at different altitudes. The weakest ones, icy comets, explode high up in the atmosphere. Stronger objects like stony asteroids will penetrate the atmosphere more deeply before they are shattered. Iron objects may reach the surface and leave a crater. Or if they are just a little weaker they may explode just above ground.

Size also comes into play. If an asteroid or comet is too big, say bigger than a few hundred meters across, it doesn't have time to "see" the atmosphere. In effect, by the time the back end of the asteroid has had a chance to find out that the front end is meeting the atmosphere, the front end has already slammed into the ground or the ocean. For big impactors, things happen too fast for the atmosphere to play a role.

Computer modeling I've done has produced a graph showing the Tunguska explosion for four different kinds of objects (page 42, left). These include fast and slow comets and carbonaceous (fragile), stony, and iron asteroids. Each of the "candidate Tunguskas" in the graph had 15 megatons of energy to start with. Each had an explosion altitude, defined as the height where the object deposits the biggest fraction of its kinetic energy into the atmosphere. The results suggest that the Tunguska event is very well explained as the explosion of a stony asteroid, or perhaps a carbonaceous one. An iron Tunguska would have reached the surface and a cometary one would have exploded far too high. Incidentally, the computer model also predicted that a 20 kiloton carbonaceous chondrite should blow up in the atmosphere at an altitude of 30 km.

According to this picture, Tunguska goes from an exotic event demanding the invocation of UFOs or black holes to a completely normal, predictable outcome for a stony asteroid entering the atmosphere with a typical velocity. This understanding is important, for it allows us to assess the contemporary hazard posed by small asteroids and comets colliding with Earth.

The Ides of Spacewatch

As of June 1993 the Spacewatch search at Kitt Peak has identified a dozen Earth-crossing asteroids smaller than 50 meters across, and the number is growing all the time. It's easy to calculate the explosive energies the objects would unleash if they struck Earth, as well as the odds of these collisions. For example, the Spacewatch observations indicate that Earth is struck by several objects with explosive energies in the 20 kiloton range every year. Revelstoke is an example of such a collision. As Revelstoke demonstrated, as long as these objects blow up at sufficiently high altitudes, they won't cause disasters on Earth's surface. But when does a dis-

The Tunguska site 1983

Donald F. Trombino

aster happen, and when not? How much should we be worried by the Spacewatch discoveries?

Once scientists have a model for the atmospheric explosions of small asteroids that accounts for Tunguska and Revelstoke, they can hope to predict the results of future collisions. My model shows a range of collision scenarios for Spacewatch objects (page 42, left). The vertical axis shows the altitude of the explosion for a given object's collision with Earth, and the horizontal axis shows the explosion's energy. For example, the Tunguska event, denoted by the solid triangle, was an explosion of about 15 megatons of energy at an altitude of 8 km or so. Revelstoke, the solid circle, was around 20 kilotons at an altitude of 30 km.

The other symbols — triangles, circles, and crosses — are the model's predictions of the fate of the twelve small Spacewatch objects discovered by June 1993. Astronomers don't yet know whether these objects are stony meteorites, carbonaceous meteorites, or comets, so I modeled each of the possibilities. The key point of comparison is the solid curve, the surface-hazard threshold line. This curve was derived from the results of nuclear weapons tests. Any explosion taking place above this line will not cause substantial damage on the ground: Trees will not be knocked over and frame houses will not be destroyed. Notice that Tunguska lies below this line and Revelstoke well above it. And the small Spacewatch asteroids virtually all lie above the line as well. This is good news because it says the small Spacewatch objects will explode too high and with too little energy to destroy buildings or topple forests.

Even if we are not threatened by the results of collisions with these objects, it's worth asking why we don't notice several 20 kiloton blasts in the atmosphere every year. Only a few thousand people noticed Revelstoke and saw it as little more than a bright fireball and some loud booms. What if Revelstoke had exploded during the day? Who pays attention to the distant thunder? And what if Revelstoke had exploded over the ocean?

Are these explanations sufficient? I'm not sure. But we should soon have an independent check. U.S. Department of Defense satellites designed to watch for nuclear explosions or missile launches may well be detecting these atmospheric explosions. It now seems likely, with the end of the Cold War, that in addition to watching for the threats of human enemies, some of these satellites will also soon be cataloguing atmospheric explosions from the cosmos. What we do know is that our current understanding of Tunguska and Revelstoke shows that these events are not freak "acts of God." They are normal, ordinary events in the life of a planet. ☐

Planetary scientist Christopher Chyba wrote this article while a National Research Council Associate at the NASA Goddard Space Flight Center. He was recently named a White House Fellow.

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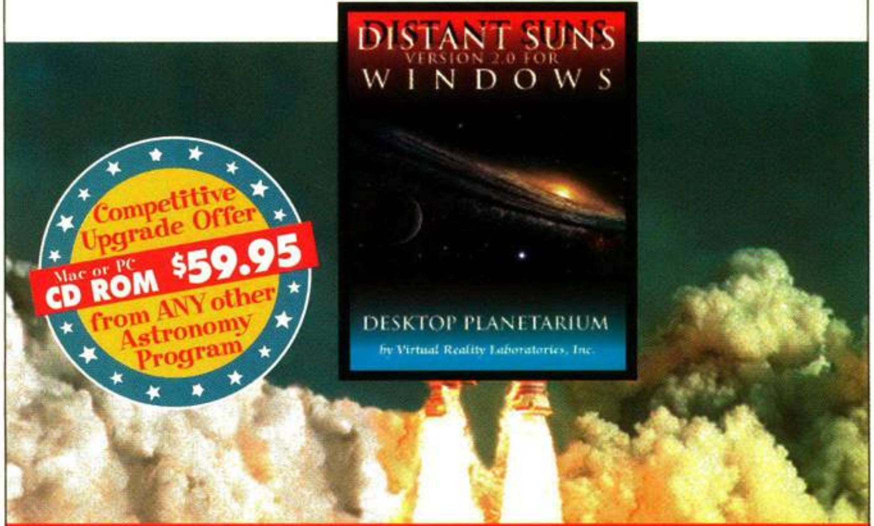
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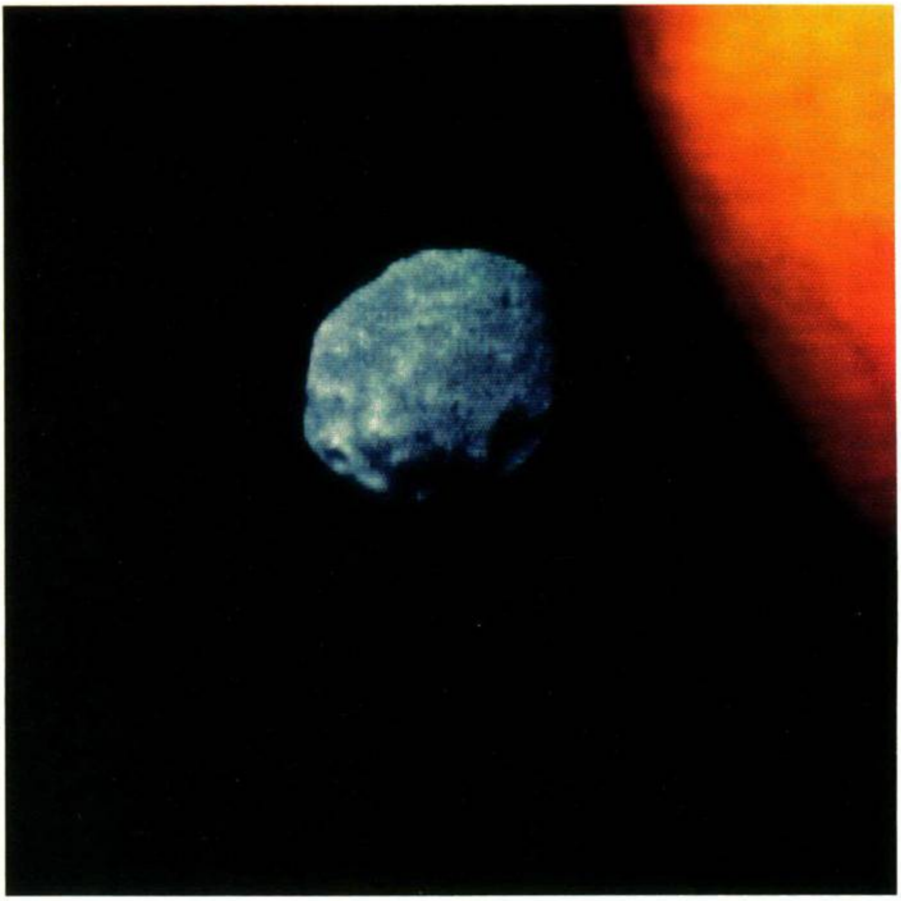
THE ODD LITTLE MOONS OF MARS

Are Phobos and Deimos just a pair of celestial hitchhikers — or actually the children of Mars?

By Damond Benningfield



Mark Robinson, University of Hawaii

PHOBOS APPEARS DARK GRAY across its surface with a bluish region at the bottom of the largest crater. The Soviet Phobos 2 spacecraft took this image in 1989.

Phobos and Deimos carry the names of the chariot horses of the Roman war god Mars — Fear and Terror. More than a century after their discovery, our understanding of these Martian moons and their origin remains almost as ethereal as their mythological namesakes.

Astronomers have long believed that Phobos and Deimos were asteroids ejected from the main asteroid belt between Mars and Jupiter by Jupiter's gravity. The Red Planet's gravity later captured these objects as they passed by. But the conclusion that the moons are escaped asteroids is no longer crystal clear.

Some researchers now propose that Phobos and Deimos are true satellites instead of captured ones. They suggest the moons formed around Mars near the time the planet itself formed.

Some evidence for this idea comes from spacecraft observations of the moons, and ground-based studies of the orbits of Phobos and Deimos provide additional support. These studies date back over a hundred years to the discovery of the moons.

Discovery

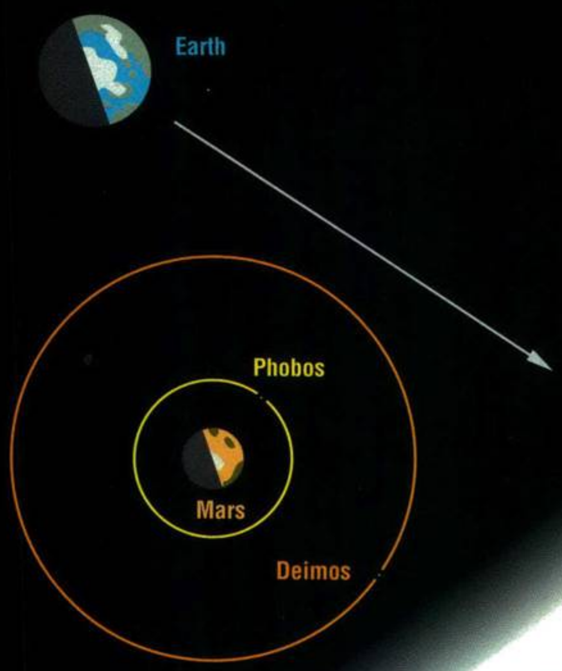
The Martian opposition of 1877 was a memorable one. Mars was near its closest approach to the Sun, so the planet loomed closer to Earth and larger and brighter in Earth's sky than at most oppositions. It was an irresistible target for astronomers who turned their telescopes toward the planet.

At Brera Observatory in Milan, Italy, for example, Giovanni Schiaparelli mapped the Martian surface. His detailed drawings revealed an intricate webbing of *canali*, or channels, crisscrossing the planet. Three decades later, Percival Lowell cited the *canali* — incorrectly translated as "canals" — as evidence of an ancient civilization on Mars. Photographs from early Mars space probes finally put Schiaparelli's channels to rest. They were nothing more than an optical illusion caused by the human eye's tendency to see patterns in random features that are at the limit of telescopic resolution.

In the United States, a carpenter-turned-astronomer made a more lasting discovery. After midnight of August 11/12, just before fog blocked his view of Mars, Asaph Hall caught a glimpse of a starlike object near the planet with the 26-inch refractor at the U. S. Naval Observatory

PHOBOS WILL CRASH into Mars in the next 50 million years. Mars' gravity is slowly pulling the satellite inward. At the same time Deimos is slowly moving away from the Red Planet.

U. S. Geological Survey (Mars) and NASA (Phobos)



PHOBOS AND DEIMOS huddle much closer to Mars than the Moon does to Earth. Mars' two moons are so small, they're just dots in this scale drawing.

ASTRONOMY: Illustration by Thomas L. Hunt

in Washington, D. C., the world's largest telescope at the time. When the skies cleared on August 16, he again aimed the refractor at the limb of the bright planet and found the object was still there. The next night Hall followed the object for two hours, confirming its identity as a Martian moon. And on this same night, he found another, slightly brighter moon orbiting closer to Mars.

Since Hall's discoveries, planetary scientists have determined the orbits and sizes of the moons. Phobos circles Mars once every 7.7 hours 6,000 kilometers above the Martian surface. It rises in the west and sets in the east three times every Martian day. Because Phobos is so close to the Martian surface, observers higher than 70° north or south latitude would not see the moon.

Deimos, at an altitude of 20,000 km, completes one orbital revolution in just over 30 hours. Being farther from Mars, Deimos would be visible to observers all over the planet except for those above 82° latitude. Because the orbital period is close to the 24.6-hour rotation period of Mars, the moon appears to stay in nearly the same place in the sky over one Martian day. This means that a Martian observer would sometimes see Deimos all day in the sky, while Earth observers see our Moon rise and set each day. At other times, Deimos would be continually below the horizon.

Like Earth's Moon, both Phobos and Deimos rotate once in the same time it takes for them to orbit their parent. Mars' gravity pulling on the potato-shaped moons has caused the rotation periods to lock into the orbital periods. As a result of this synchronous rotation, the same side of each moon always faces Mars.

Both moons would appear as little more than bright, irregular shapes to a Martian observer because they're so small. Phobos is only 27 km long at its widest point and shines at magnitude –3.9, comparable to the brightness of Venus in our sky. The diameter of Deimos is about 15 km, making it perhaps the smallest of the over 60 known satellites of the planets. (Some of Saturn's satellites may be smaller but their diameters are not well known.) Deimos appears at about –0.1 magnitude from the Martian surface, or the same brightness as the star Vega in the constellation Lyra. Being closer to Mars, Phobos would appear about five times larger than Deimos to a Martian observer, or about a third the diameter of a Full Moon seen from Earth.

The moons are dark, matching our Moon's reflectivity by bouncing only about five percent of incoming sunlight off their surfaces. The small sizes, darkness, and spectra of the two bodies are similar to those for some types of asteroids, which led planetary scientists to speculate that Phobos and Deimos are captured asteroids.

The Trouble with Capture

But there's also some evidence that the moons may have formed or accreted in orbit around Mars. For example, the remoteness of Deimos from Mars means the planet's gravity changes the moon's orbit little over time. Its nearly circular orbit has likely always been that way and couldn't have started as the highly elliptical orbit of a captured asteroid.

"We don't even know where our Moon came from, so it's tough to go to another planet and find out where its moons came from," says Tom Duxbury of NASA's Jet Propulsion Laboratory in Pasadena, California. Duxbury says the current orbits of the two moons could support either the capture or accretion theories. "They're in very circular orbits, and that's how things would accrete," he notes. But that's not proof that the moons, especially Phobos, formed around Mars. If Mars had captured Phobos, the planet's gravity acting over billions of years would tend to make its highly elliptical orbit nearly circular.

Duxbury explains that the orbits also support the idea that Phobos and Deimos may have been one body that split apart while orbiting Mars. The pull of Phobos' gravity on Mars draws energy from the moon's orbit, causing Phobos to slowly spiral in. In 30 to 50 million years, Mars' gravity will rip Phobos apart and cause it to crash into the Red Planet's surface. Debris left behind will form a thin ring around Mars. On the other hand, Deimos is slowly spiraling out. Duxbury says, "As you track the spiraling orbits of Phobos and Deimos back in time, you reach a point where the orbits are similar."

So the two moons may have once been one larger body, orbiting between the present orbits of Phobos and Deimos. But Duxbury warns that we have observations only for the last hundred years and that it's hard to determine accurately the orbits of the moons billions of years ago from this short span of measurements. He says, "I lean toward the idea that the moons accreted in orbit."

Dan Britt of the University of Arizona's Lunar and Planetary Lab says he also favors the accretion theory. His objection to the capture theory is that the capture mechanism sounds improbable.

The capture theory states that during the early history of the solar system, an extended atmosphere enveloped Mars. Jupiter's gravity kicked a number of asteroids out of the main asteroid belt into orbit around the Sun. Two of these asteroids traveled near enough to Mars to pass through the outer regions of its atmosphere. The wispy outer regions acted as a brake, snatching the asteroids from their orbits around the Sun.

Soon after the newly acquired moons entered Martian orbit, the still contracting Sun entered its T Tauri

THE MOONS' GRAY COLOR LEADS astronomers to believe they may be captured asteroids, made of the same material as this carbonaceous chondrite meteorite that fell near Allende, Mexico, in 1969.

ASTRONOMY: Jim Forbes

phase, the last step before reaching the main sequence, or stellar "adulthood." During this phase, the young Sun consumed its nuclear fuel and beamed intense radiation and streams of energetic particles throughout the solar system. This powerful solar wind blew away Mars' extended atmosphere before the atmosphere could drag the tiny satellites to an early doom.

Britt's problem with the capture theory isn't with the capture itself but with the critical timing of the disaster-preventing T Tauri wind. If the wind occurred too early, Mars wouldn't have captured the asteroids. If the wind occurred too late, Phobos and Deimos would have smashed into Mars. "We know that the T Tauri phase happens for many stars but it's too easy to invoke this mechanism," Britt says. "It's been blamed for everything from causing cavities and bunions to capturing asteroids. It's not probable."

Something that could help settle the argument is a better understanding of the composition and internal structure of the moons.

Martian Filling Stations?

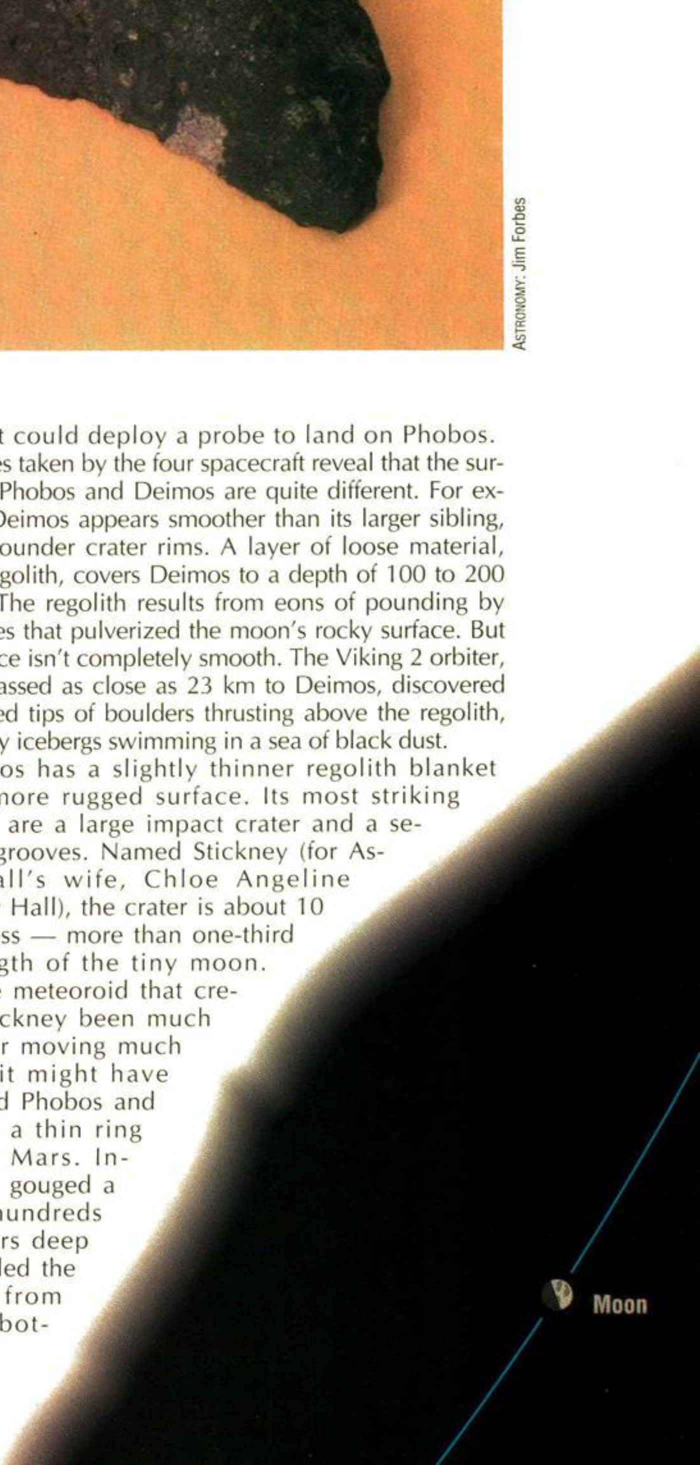
Knowledge about the chemical makeup of each moon could also help shape human exploration of Mars. If the moons contain large amounts of water, they could serve as refueling stations for interplanetary spacecraft, drastically reducing the amount of fuel ferried from Earth to Mars. "A lot of people are basing their manned exploration hopes on the idea that we have this 'gas station' in Mars' orbit," says Britt. "It would be a pity to get there and find that the pumps are empty."

Information on the surface and composition of the moons is sketchy for a couple of reasons. First, they're small and so close to Mars that it's difficult to view them from Earth without glare from the much brighter Martian surface interfering with the observation. Second, they're a relatively low priority among solar system astronomers. Moons seldom receive the same attention as their parent planets and even among moons, Phobos and Deimos are 98-pound weaklings. They lack the glitz of Io's sulfur volcanos, Triton's ice geysers, and Titan's thick atmosphere with its orangish organic haze.

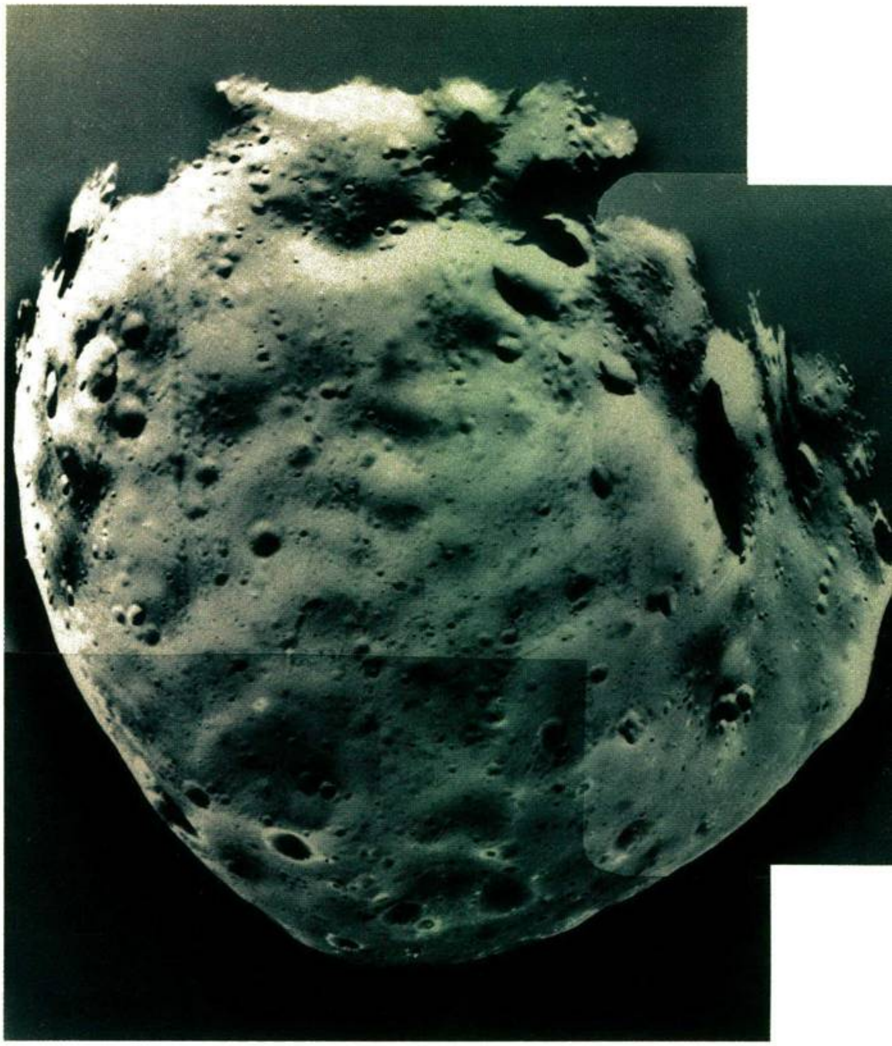
Most of what is known about Phobos and Deimos came from four spacecraft. NASA's Mariner 9 flew by Mars in 1971, followed in 1976 by two combined orbiter and lander missions, Viking 1 and 2. The Soviet probe Phobos 2 traveled to Mars in 1989 and took some pictures of its namesake, but the spacecraft failed before it could deploy a probe to land on Phobos.

Images taken by the four spacecraft reveal that the surfaces of Phobos and Deimos are quite different. For example, Deimos appears smoother than its larger sibling, having rounder crater rims. A layer of loose material, called regolith, covers Deimos to a depth of 100 to 200 meters. The regolith results from eons of pounding by meteorites that pulverized the moon's rocky surface. But the surface isn't completely smooth. The Viking 2 orbiter, which passed as close as 23 km to Deimos, discovered the jagged tips of boulders thrusting above the regolith, like rocky icebergs swimming in a sea of black dust.

Phobos has a slightly thinner regolith blanket and a more rugged surface. Its most striking features are a large impact crater and a series of grooves. Named Stickney (for Asaph Hall's wife, Chloe Angeline Stickney Hall), the crater is about 10 km across — more than one-third the length of the tiny moon. Had the meteoroid that created Stickney been much larger or moving much faster, it might have shattered Phobos and created a thin ring around Mars. Instead, it gouged a crater hundreds of meters deep and rattled the moon from top to bottom.



A THICK LAYER OF SURFACE DEBRIS COVERS both Phobos (mosaic at right) and Deimos (far right). Meteorites bombarded the surfaces, creating this soil, called regolith, as the surface fragmented. The regolith layer of Phobos is roughly 100 meters deep and that of Deimos is slightly thicker. How the weak gravity of the satellites could hold onto the dust and rocks churned up by the impacts remains a mystery.



Smashed by Rocks from Mars?

The Stickney impact probably was the most important event in Phobos' history. It may have altered the moon's entire surface and shattered its interior. The impact also suggests, but doesn't prove, that Phobos formed around Mars.

Grooves up to 200 meters wide, about 25 m deep, and several km long scar the surface of Phobos. Most of the grooves appear to radiate from Stickney, leading many scientists to conclude that they are fractures caused by the Stickney impact.

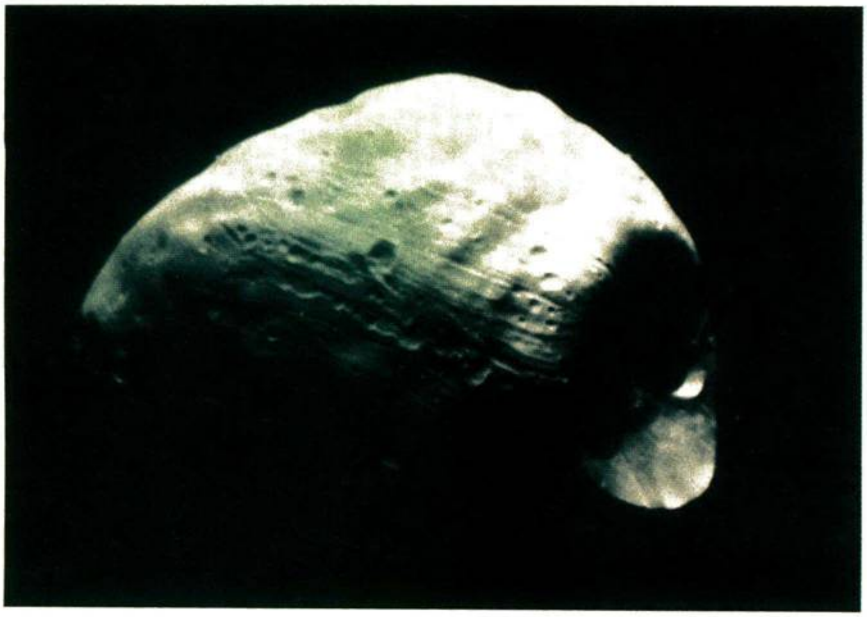
"I'm quite impressed by the geometry of most of the grooves and how they all seem to point toward Stickney," says Tom Duxbury, who was a member of the imaging team for the Mariner 9 and Viking missions. "They're widest at Stickney and they taper off and disappear as they move away."

Some planetary scientists suggest that the grooves formed when heat from the impact vaporized frozen material inside Phobos. As the gases escaped, they left empty tunnels below the surface that eventually collapsed. Still others believe that the grooves have nothing to do with the Stickney impact. Instead, they say, the grooves are the result of impacts on Mars.

According to this theory, which was presented in 1992 by J. B. Murray of The Open University in Milton Keynes, England, and his colleagues, giant impacts early in Mars' history sprayed debris thousands of kilometers into space. If Phobos lay in the path of a debris plume, the material would have sliced into the moon's surface, creating grooves or craters.

Their theory could even account for grooves and craters on the side of the moon away from Mars: Material blasted beyond the orbit of Phobos could have struck the moon's backside as it fell back toward Mars. Deimos, on the other hand, was far enough away from Mars to escape most of the impact ejecta.

If their theory is correct, it means that Phobos was in orbit around Mars at least four billion years ago when Mars and the other inner planets were undergoing an intense and steady bombardment by giant meteoroids left over from the formation of the solar system.



GROOVES RADIATING FROM Stickney Crater result from the impact that almost shattered this small world. Or material splashed from a giant impact on Mars may have gouged them out.

All photos on these pages: NASA Viking 1

Chemical Clues

Of course, knowing when Phobos was in orbit around Mars doesn't answer the question of how Phobos and Deimos got there in the first place. Their composition offers another piece of this puzzle.

Spectroscopic observations indicate that Phobos and Deimos resemble certain types of meteorites called carbonaceous chondrites — dark, rocky bodies that are rich in carbon compounds. Astronomers believe these meteorites come from asteroids in the main belt near Jupiter.

But some scientists say the moons are more like mafic rocks — material rich in magnesium and iron — and that they resemble carbonaceous chondrites only because intense solar radiation and eons of bombardment have blackened their surface.

Evidence for this comes from color images taken by Phobos 2. They reveal subtle patches of blue material inside Stickney and patches of red on the opposite side of the moon. "This was somewhat surprising," says Scott Murchie, a scientist at Brown University. "We expected all small bodies to paint themselves gray from the accumulated effects of impacts. Phobos 2's instruments found that, on average, Phobos *is* gray. But locally, there are significant departures."

The blue patches show the spectral characteristics of mafic material, indicating that the Stickney impact uncovered material deep in the interior of Phobos. Possibly thrown on top of the regolith by meteorite impacts, the red patches may contain pristine carbonaceous chondrite material from the surface of Phobos. The separation of mafic material deep in the interior and chondritic material at the surface could support the theory that Phobos and Deimos are remnants of a larger object that formed around Mars. The settling of heavy elements like magnesium and iron toward an object's center occurs only for massive bodies, not objects the size of Phobos and Deimos.

A final piece of the puzzle is the density of the two moons. Phobos 2 found that Phobos is slightly less dense than carbonaceous chondrites. Viking 1 found a slightly lower density as well for Deimos. The low density seems to support the idea the moons are captured asteroids.

If Phobos contains carbonaceous material, then its interior must contain large cracks — perhaps the result of the violent impact that created the crater Stickney. The cracks could be hollow, or they could contain water ice. If they exist, such buried glaciers could fuel future human exploration of Mars.

The density and spectra support the idea that the moons are captured asteroids, while the orbital evidence suggests that Phobos and Deimos formed around Mars. Neither case is clear-cut. The pendulum may swing back and forth between these two ideas until spacecraft return to explore the surface and composition of each moon. But with Mars Observer out of the picture and the Mars '94, Mars '96, and Mesur Pathfinder missions all concentrating on the Martian surface and atmosphere, it's not clear when we'll get our next close look at Phobos and Deimos. Thus the final answer as to whether Phobos and Deimos are truly the children of Mars remains uncertain. □

Damond Benningfield writes for the radio program "Star Date." His last article for ASTRONOMY, *"Mysteries of the Moon," appeared in the December 1991 issue.*

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**Plossl test, "SKY & TELESCOPE," p490-492, May 1988*

NEW MEADE 12" LX200 SCHMIDT-CASSEGRAINS

8" LX200
$2295

12" LX200 $3995

NEW Meade 8" LX200 Telescopes

See the Meade ad in this magazine for full specifications & details. **LX100 Drive**, 2X, 32X speed control with PPEC (Permanent Periodic Error Correction "Smart Drive") & dual-axis hand controller. **LX200 Drive**, Full electronic control with PPEC, 747 object computer memory and automatic computer controlled slewing to desired object. *NOTE:* A wedge is **not** needed for visual observing with the LX200 Drive. Select f/10 or f/6.3 (no extra charge) for your Schmidt-Cassegrain.

8" LX100 Schmidt-Cassegrain with wedge (add $105 P&S) .	**$1995**
8" LX200 Schmidt-Cassegrain with computer (add $105 P&S)	**$2295**
Wedge for photographing with 8" LX200	**$110**
10" LX100 Schmidt-Cassegrain w/super wedge (add $145 P&S)	**$2695**
10" LX200 Schmidt-Cassegrain with computer (add $145 P&S)	**$2595**
NEW! 12" LX200 (f/10 only) with computer (add $215 P&S)	**$3995**
Super Wedge for photography with 10" or 12" LX200	**$395**
8,000 Object CNGC Library (Version 2.5 software)	**$99**
Library Option 1: 10,600 obj. selected from NGC, Messier, IC catalogues ..	**$99**
Library Option 2: 64,350 celestial objects (Version 3.2 only) ..	**$149**

OTHER SCHMIDT-CASSEGRAINS

Meade 2045D 4" f/10 with motor drive (add $40 P&S)	**$699**
Meade 2080B 8" f/10 with tripod, wedge, MCOG (add $85 P&S)	**$1149**
NEW! Model 2120B 10" f/10 w/wedge, tripod, MCOG (add $125)	**$1449**

PHOTOGRAPHY ACCESSORIES

LUMICON Cassegrain EASY-GUIDER f/6 or f/10	**$225**
LUMICON Giant EASY-GUIDER for 10" f/5-f/10 operation ...	**$395**

MEADE STARFINDERS

New 8" f/6 Meade Starfinder telescopes

See the Meade ad in this magazine for full descriptions and technical specifications for 6" to 16" Starfinders. These are complete telescope systems with motor drive, mount, finderscope and 25mm (=48X) eyepiece.

6" f/8 **Starfinder 6**(add $50 P&S)	**$599**
8" f/6 **Starfinder 8** (add $60 P&S)	**$699**
10" f/4.5 **Starfinder 10** (add $75 P&S)	**$799**
16" f/4.5 **Starfinder 16** (ship. freight COD) .	**$2195**

*All Starfinder telescopes shipped directly from Meade to the purchaser. Please add the indicated shipping charge to the price. LUMICON showroom prices are $96 higher.

ACCESSORIES

LUMICON carries the full line of Meade accessories. See the Meade ad in this magazine for detailed prices and descriptions.

LUMICON Single axis drive corrector .	**$99**
LUMICON DX200 Dual-axis drive cor.	**$249**
Meade 47M Dual-axis drive corrector	**$450**
LUMICON DX2BP Dual-axis drive corrector with built-in battery pack	**$299**

LUMICON® SKY VECTOR™

Higher Performance — Lower Price

LUMICON ACCESSORIES

LUMICON, 2111 Research Dr., #5, Livermore, CA 94550 (510) 447-9570 FAX (510) 447-9589

LOW PRICE—from $399

LUMICON SKY VECTOR FEATURES:

- "GUIDE" mode leads you to object
- Digital right ascension readout to 1 min.
- Digital decl. readout to 10 arc-min.
- 4000 pulse (0.09° accuracy) encoders
- Polar alignment ***not required!***
- Motor drive ***not required!***
- Just sight two stars to align!
- Works **equally well** for alt-azimuth telescopes like Coulter Odyssey and equatorial mounts like C-8, Meade 2080.
- **No need** to enter latitude, longitude, etc.

SKY VECTOR I™ $399

NEW! With over 220 object memory including the 110 Messier and 58 best NGC objects.

SKY VECTOR II™ $499

IMPROVED — Planets, Over 3,700 Objects! With size, magnitude and full visual description.

NGC SKY VECTOR™ $699

IMPROVED!—5500 Additions / Corrections

NGC-Sky Vector
OFF ON
DIM
MODE
ENTER
UP
DOWN
LUMICON

Improved NGC SKY VECTOR with over 12,000 object memory including the planets, complete, corrected RNGC catalogue, IC catalogue, P&K planetary catalogue, & much more!

Specify Telescope Type: Meade 2045, 2080, 2120, C-8, C-11, Odyssey 8, 10, 13, 17½, Alt-Azimuth.

Ultima 8, 11 .. **add $25**, C-14 .. **add $75**

COMA CORRECTOR

Coma 1 inch off-axis 17½" f/4.5

Same field with LUMICON coma corrector; smaller, more numerous stars.

This computer-designed LUMICON 2" lens reduces coma and flattens the field for both viewing and photography. **It threads into LUMICON 2" EASY-GUIDERS for effortless installation.** This zero power lens does not change image scale nor shift focus, and all lens surfaces are multi-coated for highest efficiency. Clear aperture = 1.8".

LUMICON 48mm Coma Corrector/Field Flattener Lens	**$285.00**
LUMICON 2" EASY-GUIDER .	**$169.50**
2" EASY-GUIDER (Mamiya 645)	**$199.50**
2" Adapter for Pentax 6X7 ...	**$129.00**
2" Adapter for Hasselblad .	**$229.00**
2" Adapter for Bronica SQ-A	**$175.00**
2" Extension for viewing ...	**$26.00**

2" DELUXE BARLOW

1.8x Multiplier Lens (2" Barlow)

LUMICON 1.8x Multiplier Lens (2" Barlow)	**$235.00**

LARGE UV/DUST SEAL

Protect the optics of your 8-14" Schmidt-Cassegrain with a UV/Dust Seal. Simply thread it onto the rear cell, then attach all normal accessories. The large size fits Meade 2120, Celestron-11 and -14 & has a high quality multi coated (removable) 72mm UV filter.

Deep-Sky Filter/Dust Seal for C-8, 2080 ...	**$119.50**
UV/Dust Deal for Celestron C-8 ...	**$39.00**
UV/Dust Seal for Meade 2080, 2045	**$39.00**
UV/Dust Seal (large) for Meade 2120	**$89.50**
UV/Dust Seal for Celestron-11, -14 .	**$89.50**

LOW PROFILE FOCUSERS New! Thread-on for Odyssey

FROM $59.50

LUMICON® LOW PROFILE FOCUSERS

LUMICON now offers 3 different low-profile helical focusers. They stand only 1¼-1½" above the telescope tube. Use the 1¼" or 2" versions for viewing. Use the 2" non-rotating focuser for convenient photography with the LUMICON 2" EASY-GUIDER™.

Select your desired base-plate shape! Coulter Odyssey (thread-on installation), Flat, 7" OD, 9½" OD, 12½" OD, 16" OD, 21" OD.

LUMICON 1¼" Helical Focuser	**$59.50**
LUMICON 2" Helical Focuser 1½" high	**$65.00**
LUMICON Non-rotating Helical Focuser	**$129.00**
2" Astro Systems focuser, only 2" high	**$139.00**
3 handles for non-rotating focuser	**$12.95**
2"/1¼" adapter w/48mm filter threads	**$20.00**
2" LUMICON EASY-GUIDER	**$169.50**

LUMICON 50mm, 80mm SUPER-FINDER™

Visual Astronomers prefer the LUMICON 80mm SUPER-FINDER™, since hundreds of deep-sky objects, including most Messier objects, are visible directly. SUPER-FINDERS also make nice small portable telescopes. 80mm aperture, F=300mm coated achromat or 50mm, F=200mm coated achromat. Eyepieces and/or star diagonal are extra.

1¼" 50mm Finderscope **$59.50**, right-angle	**$59.50**
1¼" straight-thru 80mm SUPER-FINDER ...	**$169**
1¼" right-angle 80mm SUPER-FINDER ..	**$179.50**
1¼" right-angle version, w/star diagonal	**$209**
25mm Cross-hair 1¼" eyepiece (12X)	**$39**
Large mounting rings for 80mm Finder	**$55**
1¼" Star Diagonal **$39**, Mounting Brackets,	**$39.50**
1¼" 45° diagonal for correct left-right views	**$52.44**

LOTS OF ADAPTERS

2" adapter for C-8, Meade 2080, etc. ..	**$26.00**
2" adapter for C-80, C-100 refractor ...	**$39.50**
2" adapter for C-70, C-80F, C-100F fluorite	**$39.50**
2" adapter for C-6, Comet Catcher, Meade 312	**$30.00**

EXTENSION TUBES

1" long 1¼" OD thread-in extension ...	**12.00**
2½" long extension (holds 1¼" filters) .	**16.00**
4½" long extension for 1¼" eyepieces	**$25.00**
3" long extension for 2" eyepieces* ..	**$26.00**
2" long extension for 2" eyepieces* ..	**$26.00**

VIEWING ADAPTERS

2"/1¼" reducing bushing,threaded 48mm*	**$20.00**
2"/T-thread adapter, threaded 48mm* ..	**$25.00**
T-thread/1¼" adapter	**$25.00**
F/10 2" or 1¼" eyepiece viewing adapter for Giant Easy-Guider	**$39.50**
Low profile star diagonal eyepiece holder	**$16.00**
Meade 2" Diagonal/Giant Easy-Guider	**$39.50**

**Threaded to hold 48mm filters.*

Meade & Celestron
LUMICON Carries a full line of telescopes & accessories. Fast Delivery, competitive prices.

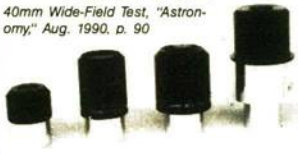
LUMICON FOR HIGH PERFORMANCE

ASTROPHOTO OF THE MONTH

NGC 253 in Sculptor. 120 minute exposure by Andrew Peters using hypered 2415 film and a **LUMICON Coma Corrector** and **2'' LUMICON Easy-Guider** in a 20'' f/5 telescope.

"I'd Pick The TELE VUE™"

40mm Wide-Field Test, "Astronomy," Aug. 1990, p. 90



Genesis 4'' f/5 4 element fluorite	**$1595**
Pronto 70mm f/6.4 apochromat w/2'' diagonal	**$798**
Pronto 70mm f/6.4 w/45° erecting prism	**$698**
Complete Equatorial Mount	**$795**
Motor Drive for above mount	**$239**
7.4, 10.4, 13, 17, 21, 26mm Plossl 50°	**$79**
1.8x or 2.5x Tele Vue Barlow Lens	**$89**
2'' Giant Barlow - 2x	**$189**
32mm Plossl, widest true field in 1¼''	**$109**
55mm 2'' Plossl, widest possible field	**$219**
15mm Wide-Field, 1¼'' eyepiece, 65°	**$135**
19mm Wide-Field, 1¼'' eyepiece, 65°	**$145**
24mm Wide-Field, "Rich-Field!" 65°	**$169**
32mm Wide-Field, 2'' eyepiece, 65°	**$239**
40mm Wide-Field, "Rich-Field!" 65°	**$299**
4.8mm Nagler, 82° field, 1¼'' eyepiece	**$149**
7mm Nagler, 1¼'' eyepiece, 82° field	**$189**
9mm Nagler, 82° field, 1¼'' or 2''	**$219**
11mm Nagler, 82° field, 1¼'' or 2''	**$235**
13mm Nagler, 82° field, 1¼'' or 2''	**$249**
12mm Nagler, Type II, 82°, 1¼''/2''	**$249**
16mm Nagler, Type II, 82°, 1¼''/2''	**$289**
20mm Nagler, Type II, 82°, 2'' only	**$340**
1¼'' Paracorr Visual Coma Corrector	**$159**
2'' Paracorr Visual Coma Corrector	**$249**
NEW! 22mm Panoptic 1¼''/2'', 68°	**$249**
NEW! 27mm Panoptic 2'', 68°	**$299**
NEW! 35mm Panoptic 2'', 68° field	**$325**

ADJUSTABLE PIGGYBACK MOUNT

The LUMICON adjustable piggyback mount is ideal for telescopes of 6-16'' aperture. It permits **both** vertical and sideways adjustment for optical alignment. Also ideal to mount LUMICON 80mm SUPER-FINDER™, large telephoto lenses and small telescopes up to about 5 lbs.

LUMICON Adjust. Piggyback Mount **$59.50**
Specify telescope size: 6'', 8'', 10'', 11'', 14'', 16''

H-ALPHA PASS FILTER

Yields spectacular contrast gains in B&W photograph with telephoto lenses. Yields pinpoint star images. Superb with hypered 2415. For color, use the Minus Violet (MV) Filter.

Specify Lens Size	**H-Alpha**	**(MV)**
46, 48, 49mm	**$59.00**	**$49.00**
52, 55, 58, 62mm	**$69.00**	**$59.00**
67, 72, 77mm	**$79.00**	**$69.00**
82mm	**$89.00**	**N/A**

Hypered 2415 film, 36 exp .. **$10.95, $3/$29**

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For phone orders please call (510) 447-9570
FAX (6 PM-9 AM PST) (510) 447-9589
LUMICON Products catalogue FREE
All foreign orders add 8% ($10 minimum)
California residents add 8.25% tax.
Prices subject to change w/o notice.
Hrs: M-F 9 am - 5 pm, Sat. 11 am - 3 pm

NEW! ENHANCED ALUMINUM DIAGONAL MIRRORS BOOST TELESCOPE PERFORMANCE

LUMICON 1.3'' & 2.1'' enhanced aluminum diagonal mirrors & 1¼'' star diagonal.

The new LUMICON diagonal mirrors have a special enhanced aluminum coating with a protective overcoating for long life. Visible reflectivity is 94-96% compared to 86-89% for standard aluminum coated mirrors. The extra 5-10% transmission is like adding up to an inch of aperture! The substrate is fine annealed Pyrex flat to 1/8 wave.

1.32''	**$39.50**	1.52''	**$45.00**	1.83''	**$49.50**
2.14''	**$59.50**	2.60''	**$75.00**	3.10''	**$99.50**

ENHANCED ALUMINUM STAR DIAGONAL

90° star diagonals with 96% reflectivity enhanced aluminum mirrors in a CNC machined black anodized aluminum body. Performance far exceeds prism diagonals.

1¼'' (1.32'' mirror)	**$99.50**
2'' (1.83'' mirror)(see photo above)	**$159.00**

LUMICON FILTERS — BEST IN THE WORLD!

"The LUMICON OIII proved to be our favorite... It gave the greatest contrast gain."
ASTRONOMY February 1991

AMAZING OIII FILTER™

Helix Nebula, NGC 7293 in Aquarius. Bright and easy with Lumicon Oxygen-III Filter.

The ultimate in filter performance! The Lumicon Oxygen-III Filter has a contrast twice as high as the high performance Lumicon UHC Filter™. Use the Oxygen-III Filter for observing the very faintest planetary and diffuse emission nebulae. Also gives incredible views of bright nebulae (like M-27, M-17, etc.) from urban locations. Bandpass is 11nm, transmission is 90-96% for both O-III lines at 496nm and 501nm.

SEE THE HORSEHEAD!

Horsehead Nebula in Orion. This faint nebula is seen best with a LUMICON H-Beta Filter. Photo by J. Marling using a Deep-Sky Filter.

"I CAN SEE THE VEIL NEBULA!"

Rich Zepernick saw the Veil Nebula for the very first time with a **LUMICON UHC Filter**. He stated, *"It was actually there! and not just around 52 Cygni, but the whole loop! Words cannot possibly express my feelings. I don't know how I managed without these filters."*
Rich Zepernick, Cresskill, NJ

DEEP-SKY FILTER™

BEST for Astrophotography!

"Stunning is all I can say," says noted astrophotographer Jack Newton. Great for BOTH color and black and white photography.

BEST WIDE-BAND FILTER!

"Based on our tests we'd recommend a LUMICON Deep-Sky and Oxygen-III as complementary filters. The LUMICON Deep-Sky Filter clearly had the best contrast for ***reflection*** *nebulae."*
Astronomy, Feb. 1991

	Premium*
0.96'' LUMICON DEEP-SKY Filter threads into most 0.96'' eyepieces	**$59.50**
1¼'' LUMICON DEEP-SKY Filter threads into most 1¼'' eyepieces	**$79.50**
48mm LUMICON DEEP-SKY Filter (1.7'' aperture), threads into most 2'' eyepieces. Also fits LUMICON EASY-GUIDERS	**$119.50**
2'' LUMICON DEEP-SKY Filter (1.5'' aperture), threads into most 2'' eyepieces. Also has male & female camera T-threads for prime focus photography	**$119.50**
72mm LUMICON Giant DEEP-SKY Filter (62, 67, 77mm adapter, $8)	**$299.50**
2'' Rear Cell Filter, fits SCT's ... Deep-Sky, **$119.50** UHC, O-III, H-Beta,	**$199.50**
1¼'' LUMICON UHC Filter threads into most 1¼'' eyepieces	**$99.50**
48mm LUMICON UHC Filter (1.75'' aperture) fits most 2'' eyepieces	**$199.50**
Set of both premium **DEEP-SKY** and **UHC Filters** (Save 11%) ... 1¼'' **$159.50**; 48mm	**$279.50**
LUMICON H-BETA Line Filter (9mm bandpass at 486nm). For the California Nebula, Horsehead Nebula, and other extremely faint nebulae. 1¼'' ... **$99.50, 48mm**	**$199.50**
Oxygen-III Filter for very faint planetary and diffuse nebulae, 11nm bandpass at 496nm and 501nm O-III lines ... **1¼'' $99.50, 48mm**	**$199.50**
Telephoto lens adapter for 2'' or 48mm filter. Select 46, 49, 52, 55, 58mm	**$6.95**
Universal adapter for 1¼'' filters. Adapts the 1¼'' filters to any 1¼'' eyepiece	**$16.00**
Universal adapter for 48mm or 2'' filters. Allows use of any 1¼'' eyepiece	**$20.00**

**Premium filters are currently the best in the world. All Lumicon filters include individually measured transmission data.*

DEEP-SKY ASTROPHOTOGRAPHY

SR-V 3200 NEW FILM

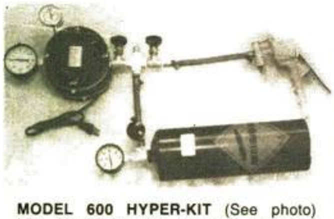
FILM HYPERSENSITIZATION KITS†

LUMICON HYPER-KITS™ yield 3-15x film speed gain in long exposures. They are safe & simple to use. Easy HYPER-KIT includes a chamber with all controls and fittings, thermometer, a refillable cylinder of non-flammable forming gas & hand-operated vacuum pump.

U.S. Patent 4,473,636

MAKE YOUR OWN HYPERED FILM

MODEL 300 HYPER-KIT sensitizes any 35mm film in hours. Best for 2415. Achieves highest possible film speeds **$325**



MODEL 600 HYPER-KIT (See photo) Like the Model 300, but also sensitizes 120/220 larger format film and small glass plates **$395**

MODEL 1200 HYPER-KIT is for 4X5'' plates and film up to 5X7''. Has 2 gas cylinders and includes temperature controller ... **$595**

Temperature controller for any HYPER-KIT **$65**

Electric Vacuum Pump, Model R-10 **$325**

GUIDE OFF-AXIS FOR LOVELY ASTROPHOTOS

All **LUMICON EASY-GUIDER™** off-axis guiders† have both radial and 360° rotational adjustments for 5X easier guide-star selection, use 48mm filters, 360° camera rotation, large prisms for bright guide-stars.
Specify Camera and Telescope type.
U.S. Patent 4,448,500

NEWTONIAN EASY-GUIDER™

Full aperture. Installs in seconds. Specify 2'' or 1¼''.

NEWTONIAN EASY-GUIDER	**$169.50**
3X Relay Diagonal (see photo)	**$89.50**
Illuminated reticle eyepiece system	**$99.50**

Guider for Hasselblad **$350**, Mamiya 645 **$199**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

CASSEGRAIN EASY-GUIDER™

For C-8, Meade 2080, Cynamax-8. Includes 50mm achromatic lens for f/5.8 operation—3X shorter exposures! **Superb rich field viewing, too!**

CASSEGRAIN EASY-GUIDER **$225.00**
Adapter for Hasselblad **$198,** Mamiya 645 **$98**
Pentax 6X7 **add $119;** Pentax 645 **add $139**

GIANT EASY-GUIDER™

For Celestron-11, C-14, and the 10'' Meade 2120. Includes 80mm clear aperture achromatic lens for edge-to-edge illumination & pin-point star images. F-ratio adjustable f/4-f/11. **Also yields unmatched Rich-Field viewing.**

GIANT EASY-GUIDER **$395.00**
48mm DEEP-SKY Filter ordered with any EASY-GUIDER (SAVE $20) ..... **add $99.95**
Adapter for Hasselblad **$229,** Mamiya 645**$129**
Pentax 6X7 **add $129;** Pentax 645 **add $149**

WHAT DO YOU NEED?

1. Illuminated reticle eyepiece **$99.50**
Lumicon 12mm eyepiece system has adjustable LED illumination, dual crosslines, battery pack.

2. Cable release for long exposures .. **$9.95**

3. **LUMICON Digital Drive Corrector** . **$249**
Dual-axis drive corrector is essential for astrophotography and/or field use of your telescope. 30Hz/90Hz variable output controls telescope drive. 60Hz digital reference ±12VDC Declination control output. Both 110VAC and 12VDC input for home or field use. Dec. reverse switch for Newtonians.

Declination motor (state telescope) ... **$109**
Variable dec. speed drive w/built-in 5AH battery **$299**

Kodak
SR1600
Scotch
1000

HYPERSENSITIZED FILM

LUMICON Hypersensitized film is essential for good deep-sky astrophotography. Deduct 10% for 3 or more rolls (mixed o.k.). ***No C.O.D.s.***

Film Type, 35mm	**Exposures**	**Price**
2415, Ultra-fine B&W, red sens.	36	**$10.95**
SR-G3200, fastest of all, color neg	24	**$13.95**
Kodak Ektar 1000 fast, fine grain	24	**$12.95**
Fuji HG400 fine grain color neg.	12	**$10.95**
3M 1000, fastest slide film	12	**$12.95**
Fujichrome RD100, fine grain slide	24	**$12.95**
D-19 B&W Developer	1 gal.	**$6.95**

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Meade Advanced Products

LX200 SCHMIDT-CASSEGRAINS

YOUR CHOICE
F/6.3 OR F/10
SCT OPTICS

LX200

IN STOCK FOR SAME DAY SHIPPING

LX200 SERIES

The new LX200 series offers, for the very first time, an easy to use, affordable, fully computerized slewing telescope. For "painless" observation simply align the telescope (using the LX200 computer) and enter any of the 747 objects contained in its built-in library and the LX200's PPEC Smart Drive will automatically slew to that object at an incredible 8° per second. To take great astronomical photos just add the optional equatorial wedge for accurate polar axis tracking.

LX200 8" .. $2295 LX200 10" .. $2595

Wedge (8")	110	Superwedge (10")	395

Additional Object Library - adds 8000 CNGC objects to the LX200's built-in computer library 99

SSC SCHMIDT-CASSEGRAINS

YOUR CHOICE
F/6.3 OR F/10
SCT OPTICS

SSC-8 & SSC-10

IN STOCK FOR SAME DAY SHIPPING

Introducing Meade's new line of large aperture Schmidt-Cassegrain telescopes. These extremely rigid, LXD equatorial mounted instruments featuring Enhanced Multi-Coatings, fulfill the advanced astronomer's need for a solid, flexible mounting system with a choice of optional, state-of-the-art computer or advanced electronic systems. These mounts can also accomodate refractors such as the ED/APO optical tubes.

SSC-8 & SSC-10

Both the SSC-8 8" & SSC-10 10" are available in f/6.3 or f/10 configurations and include the LXD-600 Equatorial mounting with worm gear slow-motion controls.

SSC-8 8" .... CALL SSC-10 10" .. CALL

#1664 Electronic Drive System	$369^{95}
#1697 Computer Drive System	$695^{95}

STANDARD SERIES SCHMIDT-CASSEGRAINS

2045D *"The truly portable scope"*	CALL
Case for 2045D .... **75.50** Tripod & Wedge	**234.50**
Piggyback Bracket for 2045D	**15.95**
2080A *"Perfect for the beginner"*	**$1069**
2080B with SMC multicoatings	**1149**
2120A *"The best value 10" SCT"*	**$1379**
2120B with SMC multicoatings	**1449**

STARFINDER NEWTONIANS

The new Starfinder telescopes represent the best value in Newtonians.

Each Starfinder telescope features Meade's hand figured optics, a precision equatorial mount with integrated motor drive, setting circles & stand.

STARFINDER 6 6" F/8	**$599.95**
STARFINDER 8 8" F/6	**$699.95**
STARFINDER 10 10" F/4.5	**$799.95**
STARFINDER 16 16" F/4.5	**$2195**

STARFINDER ACCESSORIES

Dust cover for Starfinder 6/8/10	**29.95**
#43 Drive Corrector runs scope on 12v DC	**88.50**

4500 NEWTONIAN CALL

MEADE REFRACTORS

285 60mm Altazimuth Refractor	**309**
227 .... **179.95** 224	**106.95**
390 90mm Altazim. Refractor	**CALL**
395 90mm Equatorial Refractor	**CALL**

MEADE FILTERS

SERIES 4000 COLOR (1.25")

#8 Lt. Yel, #11 Yellow-Green, #12 Yel, #21 Orng, #23A Lt. Red, #25A Red, #38A Dark Blue, #47 Violet, #56 Lt. Grn, #58 Grn, #80A Blue, #82A Lt. Blue .... **@12.95**

SET #1 4 Filters: #12 Yellow, #23A Lt. Red, #58 Green, #80A Blue	**49.95**
SET #2 4 Filters: #11 Yellow-Green, #25A Red, #47 Violet, #82A Lt. Blue	**49.95**
SET #3 4 Filters: #8 Lt. Yellow, #21 Orange, #38A Dark Blue, #56 Lt. Green	**49.95**
Series 4000 Moon Filter: ND.96	**15.95**

SERIES 4000 NEBULAR

BROADBAND FILTERS *ALL IN STOCK!*

#908B (1.25")	**79.95**	**#910B** (2")	**119.95**
#911B (rear cell thread)			**99.95**

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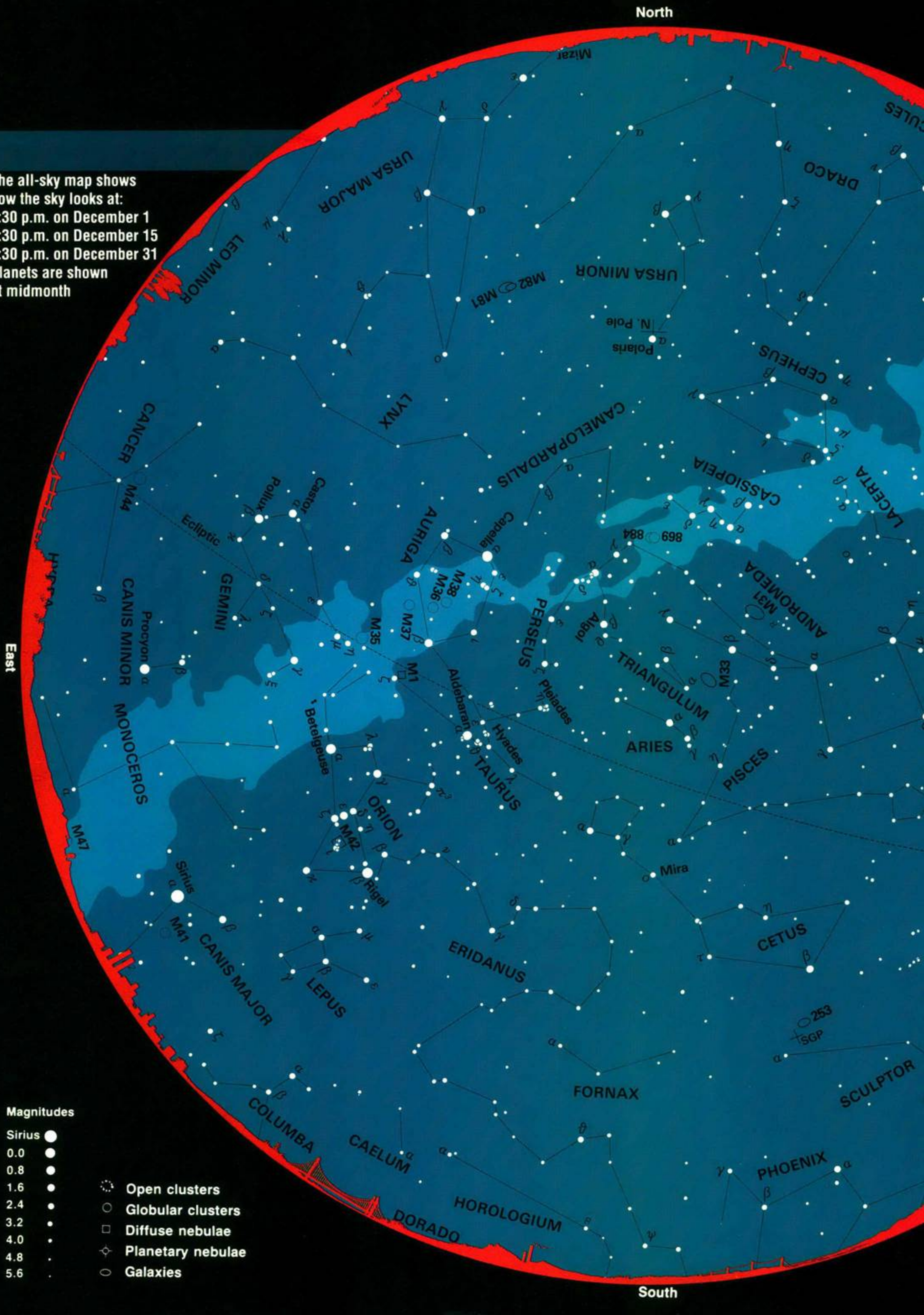
The all-sky map shows
how the sky looks at:
9:30 p.m. on December 1
8:30 p.m. on December 15
7:30 p.m. on December 31
Planets are shown
at midmonth


North
South
East
Mizar
URSA MAJOR
LEO MINOR
DRACO
URSA MINOR
M82
M81
N. Pole
Polaris
CEPHEUS
LYNX
CAMELOPARDALIS
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M44
Pollux
Castor
Ecliptic
CASSIOPEIA
LACERTA
AURIGA
Capella
884
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ANDROMEDA
M31
GEMINI
CANIS MINOR
Procyon
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M36
M35
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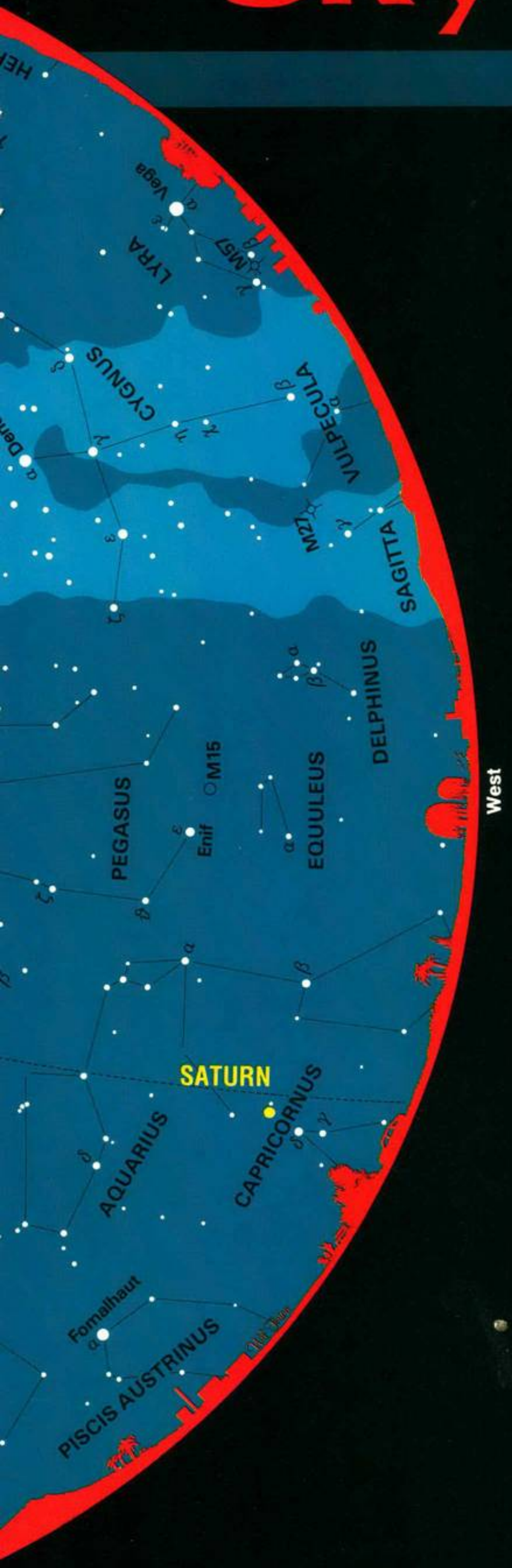
PERSEUS
Algol
TRIANGULUM
M33
M1
Aldebaran
Pleiades
Hyades
ARIES
PISCES
MONOCEROS
Betelgeuse
TAURUS
ORION
M42
Rigel
M47
Sirius
M41
Mira
CETUS
CANIS MAJOR
LEPUS
ERIDANUS
253
SGP
FORNAX
SCULPTOR
COLUMBA
CAELUM
PHOENIX
HOROLOGIUM
DORADO
Magnitudes
Sirius
0.0
0.8
1.6
2.4
3.2
4.0
4.8
5.6
Open clusters
Globular clusters
Diffuse nebulae
Planetary nebulae
Galaxies

Sky Almanac

December 1993



Map Art by Wil Tirion

- ***Geminid Meteor Shower Peaks.*** The New Moon casts no light on the night of December 13/14, when the Geminid meteor shower is at its best. You can expect to see roughly 60 Geminids per hour on that night.

- ***Ursid Meteors Also Look Promising.*** Though not as heralded as the Geminids, the Ursid meteor shower often puts on a good display. This year the shower peaks on the morning of December 22, when you should see 15 to 20 meteors per hour after the gibbous Moon sets.

- ***Comet Encke Returns.*** Three times every decade, Comet Encke returns to the inner solar system. During December and January, the comet is well placed in the evening sky for observers with a small telescope.

- ***Jupiter Bright in the Morning Sky.*** This month Jupiter comes back into prominence shortly before dawn. Look for the –1.8-magnitude planet low in the southeast just before twilight commences.

- ***U Orionis Near Maximum Brightness.*** The variable star U Orionis should shine at 6th magnitude in late November and early December. Start observing U Ori now so you can follow its slow fade over the coming months.

Calendar of Events

6 Last Quarter Moon is at 10:49 a.m. EST
10 The Moon passes 4° south of Jupiter, 3 a.m. EST
The Moon is at perigee (227,022 miles from Earth), 9:08 a.m. EST
12 Mercury passes 5° north of Antares, 5 p.m. EST
13 New Moon is at 4:27 a.m. EST
Geminid meteor shower peaks
15 The Moon passes 3° north of Neptune, 7 a.m. EST
The Moon passes 4° north of Uranus, 8 a.m. EST
18 The Moon passes 7° north of Saturn, 5 a.m. EST
20 First Quarter Moon is at 5:26 p.m. EST
21 Winter solstice is at 3:26 p.m. EST
22 The Moon is at apogee (251,354 miles from Earth), 2:50 a.m. EST
Ursid meteor shower peaks
26 Mars is in conjunction with the Sun
28 Full Moon is at 6:05 p.m. EST

Eye on the Sky

by Deborah Byrd

A PAIR OF METEOR SHOWERS

The Geminid meteor shower peaks on December 13/14. This is one of the strongest meteor showers of the year, and this year the Moon is happily missing from the night sky during the time when the most meteors will be flying.

The Geminids derive from a stream of particles left behind by an asteroid called 3200 Phaethon that may be the spent nucleus of a comet. The geometry of how Earth encounters the Geminid stream creates an unusual effect: Although most meteor showers are much better after midnight, the Geminids are also good in the evening. Earth traverses the stream between December 4 and 16. You'll see an increasing number of meteors until the night of December 13/14; then afterward the number falls off rapidly.

Rick Schmidt

A GEMINID METEOR FLARES brilliantly below Procyon and to the left of Sirius. Such fireballs are fairly common during the Geminid shower, which peaks this year on the night of December 13/14.

You'll know you are seeing a Geminid meteor if you trace its path backward in the sky and find that it has come from a point in the constellation Gemini the Twins. This point, called the radiant, lies near the bright star Castor in this constellation. (To find out more about this meteor shower, see "Catch the Geminid Meteor Shower" on page 80.)

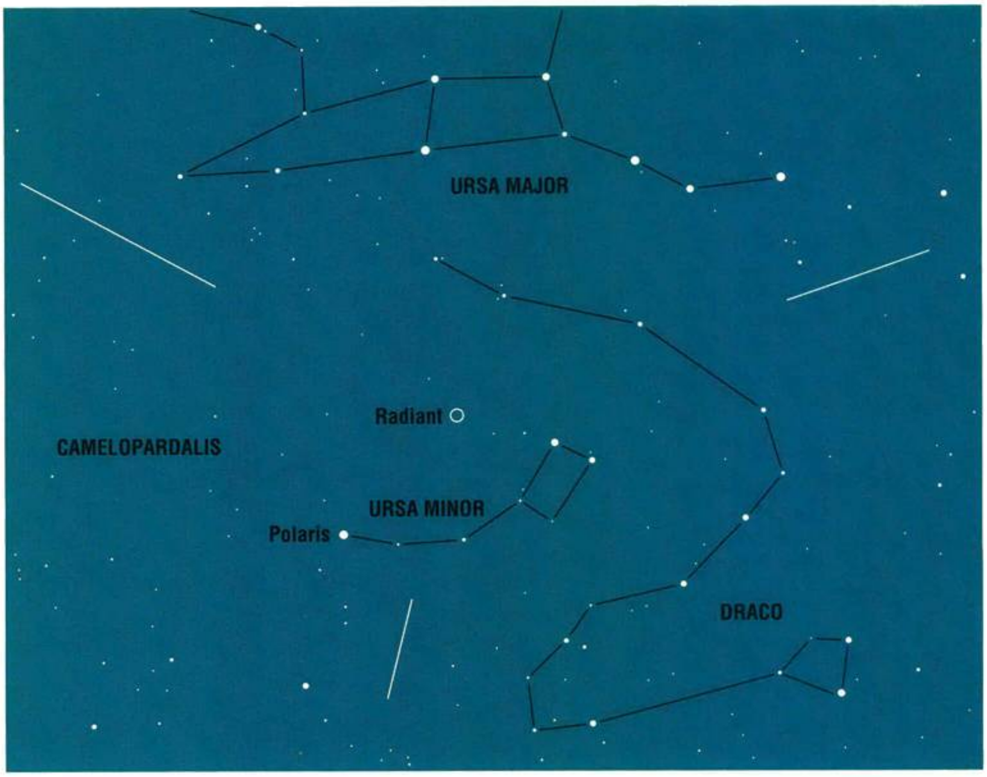
A lesser known shower, the Ursids, peaks on the morning of December 22. This shower is named for the constellation Ursa Minor the Lesser Bear, which contains the often-mentioned (but less-often-identified) Little Dipper asterism. The radiant for the Ursid meteor shower is near the star Kochab, the brightest star in the bowl of the Little Dipper.

If you live anywhere north of 15° north latitude, the radiant of the Ursid meteor shower is in the sky all night. But the Moon has a waxing gibbous phase during the shower's peak and its light will wash all but the brightest meteors from view until the Moon sets shortly after midnight. Your best bet for Ursid-watching is in the hours before dawn on December 22. (The radiant is highest at dawn anyway.)

Ursid meteors derive from Comet Tuttle, which was discovered in 1790. In 1986, some observers reported seeing over 100 Ursid meteors per hour. That accounts for the surge of interest in recent years in this previously neglected shower. On average, you can expect to see 15 to 20 meteors per hour.

You don't need a telescope or binoculars to watch a meteor shower. The only requirements are a dark sky — with the Moon out of the way and a good distance between you and any city lights — and a wide-open area where you can see most of the sky.

And remember that two or more observers can watch a meteor shower together. Each person may want to watch a slightly different region of the sky, shouting the alert when a meteor slides into view. Why not share the Geminid or Ursid meteor shower with someone this year?



MORE METEORS WILL STREAK across the sky on the morning of December 22, when the Ursid meteor shower reaches its peak.

THE SUN SINKS SOUTHWARD

The December solstice comes at 3:26 p.m. EST on December 21. That day, the Sun travels its lowest path as seen from the Northern Hemisphere. If you live in the Northern Hemisphere, you have your longest noontime shadow for the year on the day of the solstice.

Most people call this the winter solstice, but I have a hard time doing that, especially this year. On or around this solstice, I hope to be basking in the midnight sun during the height of summer in Antarctica. But from the Northern Hemisphere, this date marks the first day of winter and is the shortest day and longest night of the year. There are 10 hours and 55 minutes of daylight at 20° north latitude today, 9 hours and 20 minutes at 40° north, and only 5 hours and 52 minutes at 60° north. And of course, there's no sunlight at all above the Arctic circle.

The word solstice comes from the Latin roots "sol" meaning "Sun" and "sistere" meaning "to stand still." At the solstice, the Sun stands still in the sense that its southward motion relative to the background stars comes to a stop. After the solstice, the Sun's path starts shifting northward. All this is because Earth tilts on its axis by 23.5° as our planet orbits the Sun.

You might imagine how different things would be on Earth if our planet's axis of rotation were oriented differently. Think about Earth lying on its side as it spins, with its axis of rotation flat in the plane of our orbit around the Sun. Then one of Earth's poles would have sizzling summers with the Sun always overhead for weeks. Meanwhile, the other pole would be freezing cold, with no Sun at all. That's actually the case with the planet Uranus, but its winters and summers last much longer than ours because it orbits the Sun only once every 84 years.

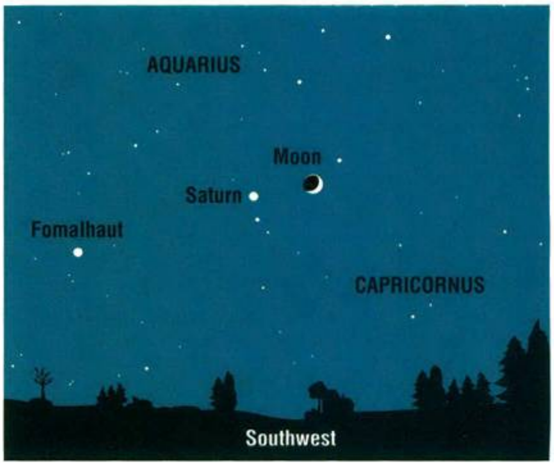
DECEMBER'S PLANETS

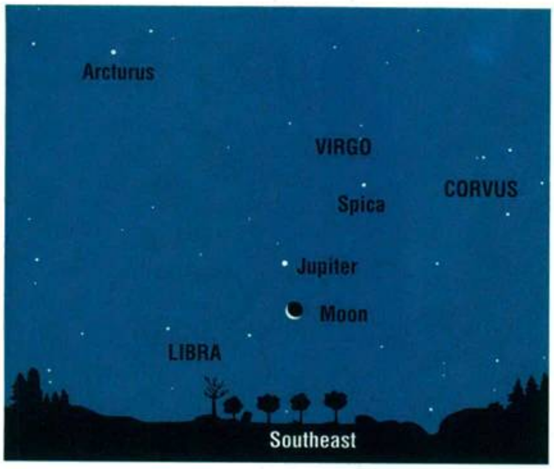
Saturn is the only bright planet in the evening sky this month. The 0.8-magnitude planet lies due south at sunset and can be found in the southwest after twilight ends. Saturn is now steadily and noticeably edging toward the Sun's glare. Look for it near the waxing crescent Moon on the evening of December 17.

The largest planet in our solar system, **Jupiter**, can be seen in the southeast before dawn. Although it is low in the sky when dawn breaks in early December, it rises higher as the days pass. Jupiter is easy to spot because it is so bright at magnitude –1.8. The planet ranks fourth in brightness behind the Sun, the Moon, and Venus.

Jupiter begins the month 11° east of the 1st-magnitude star Spica in the constellation Virgo the Maiden. This star represents an "ear of wheat" in the maiden's hand. By month's end, Jupiter has slid eastward from Virgo into neighboring Libra and can be seen about 16° from Spica. Look for Jupiter near the waning crescent Moon on the mornings of December 9 and 10.

SATURN SINKS toward the horizon on December evenings, but is still quite high as twilight ends. Look for (and try photographing) the ringed planet on the 17th, when the crescent Moon passes by.





BRILLIANT JUPITER shines conspicuously in the southeast before dawn. You can see it near the waning crescent Moon on the morning of December 10.

You will not see **Mars** this month. It is in conjunction with the Sun on December 26/27.

You will see the two inner planets, **Mercury** and **Venus**, although you may need binoculars to pick them out of the twilight glare. Both appear low in the east-southeast just before sunrise during the first week of December. On the 1st, you can spot Mercury 10° above the horizon 30 minutes before sunrise. It shines at magnitude –0.6. Venus lies only 4° high but is much brighter at magnitude –3.9. Both of these inner planets will lie on the far side of the Sun — a configuration called superior conjunction — in January.

THE STARRY SKY

This month look for Eridanus the River, one of the longest and faintest constellations. You can trace the River's path from the 3rd-magnitude white star Cursa near brilliant Rigel, which lies in Orion, west in a great loop in the southern sky, and then down again to where the River disappears over the southern horizon.

At times, I've glimpsed what for most people lies beyond that southern horizon: Eridanus ends at one of the sky's brightest stars, Achernar, but this star is invisible from all but the southernmost portions of the United States. Even from there, Achernar makes only a tiny arc above the southern horizon. This month it executes that arc in midevening.

The name Achernar means "the end of the river." The star lies at a declination of –57°, nearly as far south as the legendary Southern Cross. You cannot see it from farther north than about 30° north latitude. It shines at magnitude 0.5 from a distance of 85 light-years.

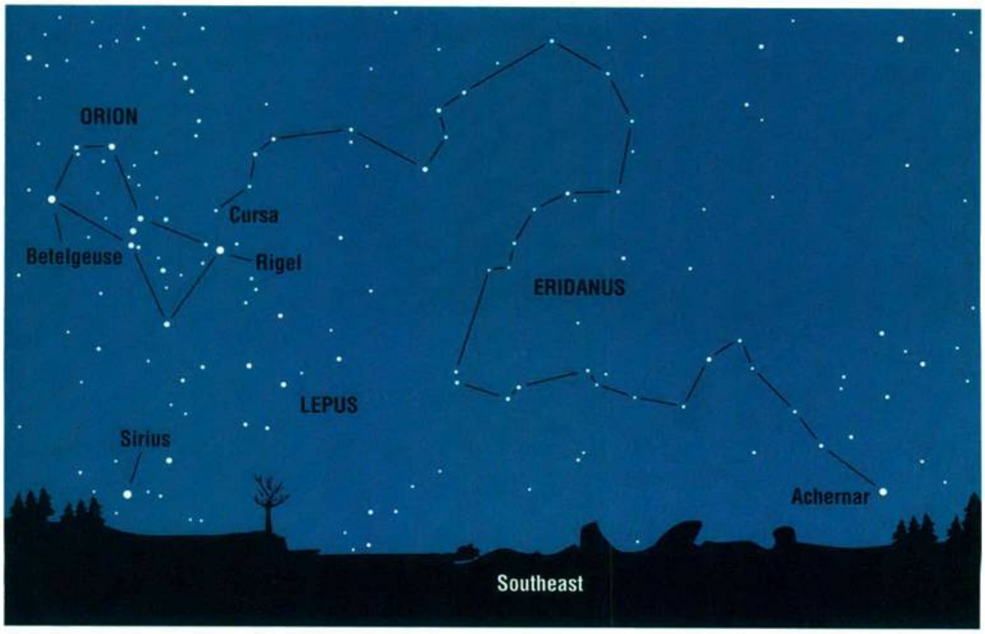
Even without Achernar, however, the constellation Eridanus is worth seeing. It is faint, consisting mostly of 4th-magnitude stars, so look for it under a dark sky. Eridanus has been called the "river of heaven," "great river of the sky," or "river of Orion." It was known as a river to stargazers who lived on the shores of the Mediterranean and in the Middle East very long ago. This constellation has frequently been associated with a large river of a particular region such as the Sumerian Strong River, the Ganges, the Nile, the Euphrates, or the Po.

In Greek mythology, Eridanus is associated with the legend of Phaethon (the same mythological being for whom the parent object of the Geminid meteor stream is named). He was the son of the Sun-god Helios.

One day, Phaethon cajoled his father into allowing him to drive the Sun-chariot across the sky. Naturally, the boy lost control of the fiery horses. The chariot plunged perilously close to Earth, creating what we today call the Sahara Desert. When Zeus saw that all of Earth might be destroyed, he hurled a thunderbolt at the boy and killed him, and his burning body fell into the River Eridanus. □

Deborah Byrd's daily "Earth & Sky" radio series can be heard on 470 radio stations in the United States, Canada, Puerto Rico, and the South Pacific.

ERIDANUS THE RIVER MEANDERS across the southern sky on December evenings. The river's source lies just west of Rigel, which is in Orion, while the mouth of the river is marked by bright Achernar.



Through the Eyepiece

by Rick Shaffer

RETURN OF AN OLD COMET FRIEND

The handwriting has been on the wall for the past couple of months. If you've been watching the skies closely, you've seen most of the bright planets creeping ever closer to the Sun. Now as December rolls around, only Jupiter and Saturn appear in a dark sky, and both of them lie near the horizon. Fortunately some other noteworthy objects grace the early winter sky. They should provide you with more than enough viewing opportunities to keep you and your telescope busy during the holiday season.

First up is one of the more famous periodic comets, Comet Encke. Encke lies in the evening sky all month among the background stars of southern Pegasus. In early December, Encke glows feebly at magnitude 12, but it brightens rapidly. By the end of the year, it shines around magnitude 10. Encke will be at its best in January, when it will shine between 7th and 8th magnitude. Your best chance to find Encke in December should be around mid-month, when the Moon is out of the sky. Viewing in early and late December is hindered by bright moonlight.

Because Encke is not a particularly bright comet in December, you'll have to be patient to find it. Use the finder chart or table of coordinates at right to pinpoint its position in the sky (the chart shows stars down to 12th magnitude). The gateway to this area are the stars of the Y-shaped Water Jar asterism in Aquarius. In December Encke lies roughly 5° north of this asterism, just over the border into Pegasus. Fortunately, Encke moves very slowly relative to the background stars all month, a total of just 4°, so you won't have to learn a new starfield each time you want to observe it.

Start with your lowest-power eyepiece, centering the field of view on the comet's position. Because it's fairly dim and moonlight may interfere, Encke likely won't pop out at you in this low-power field. If you can't spot it in the low-power field, be sure you've centered the comet's position and then insert your next highest power. The increase in power should heighten the contrast enough to allow you to detect the comet above the sky background. If the contrast is still not optimal, try increasing the power one more time.

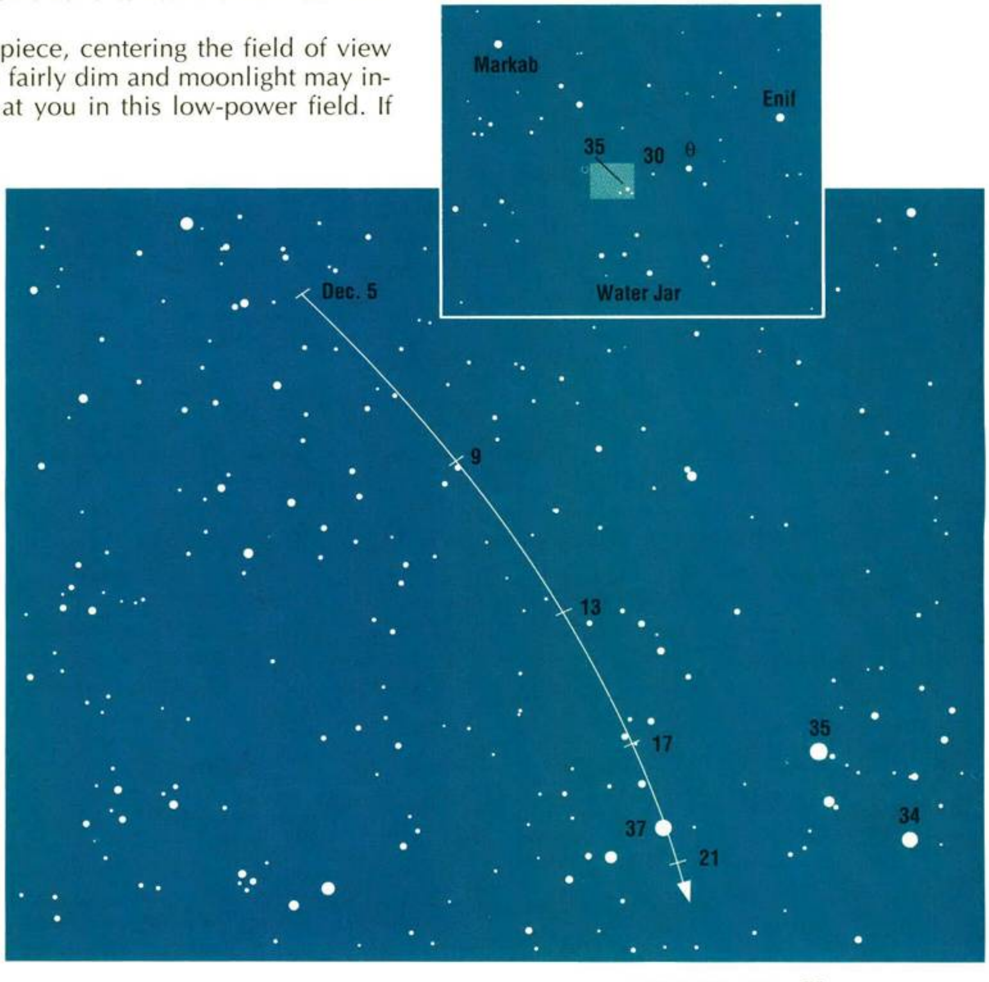
If you still can't spot Encke, don't give up. A useful technique is to look at the field at medium power and then nudge your telescope slightly. As the telescope vibrates, the image will blur. But your eye-brain combination can detect a dim object more easily if it is moving than if it's standing still. (Alas, if you have an extremely sturdy mount, you may not be able to take advantage of this trick.)

Comet Encke has a long history. French astronomer Jean Louis Pons, a former janitor at the Marseille Observatory, discovered the comet in 1818.

COORDINATES FOR COMET ENCKE

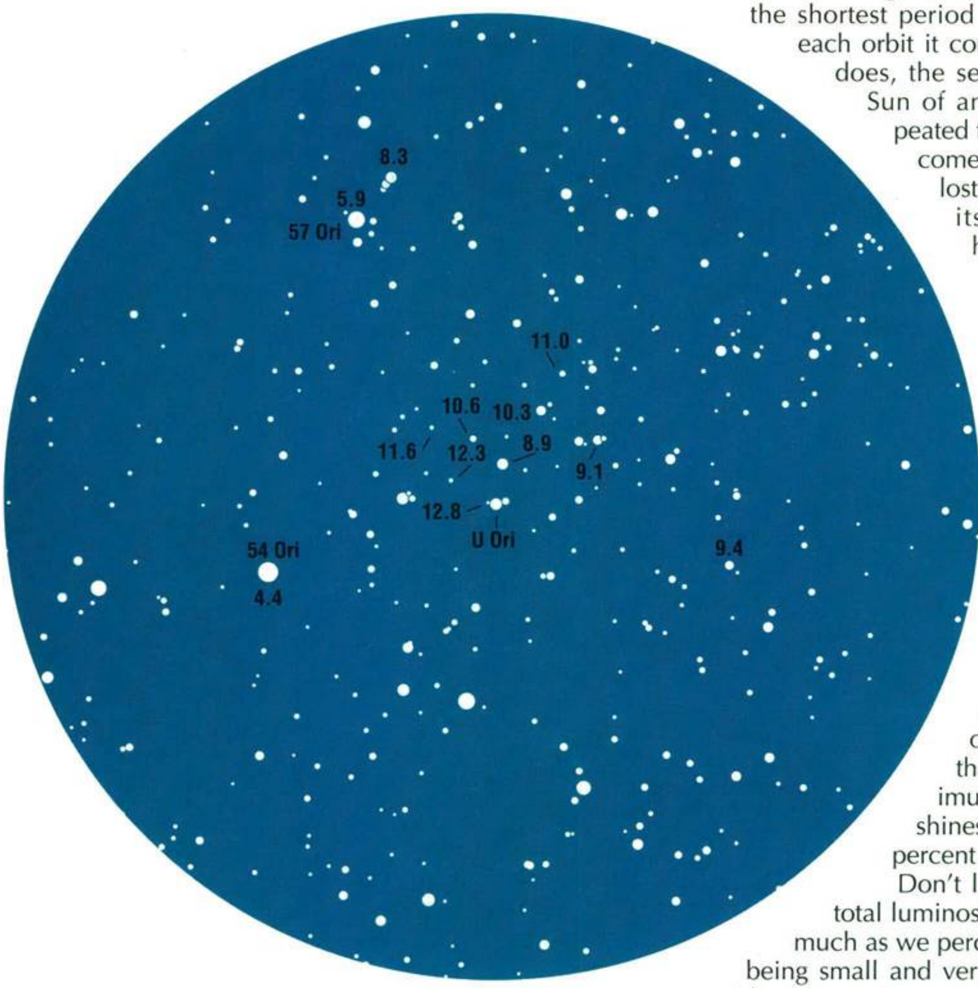
Date	R.A. (2000)	Dec.
Dec. 5	22h34.9m	6°16'
Dec. 9	22h32.8m	5°41'
Dec. 13	22h31.3m	5°11'
Dec. 17	22h30.3m	4°43'
Dec. 21	22h29.8m	4°19'

A FAINT, FUZZY GLOW in southern Pegasus heralds the return of Comet Encke to the inner solar system. Track down the 11th-magnitude comet on the Moon-free evenings during mid-December. Positions are shown for 10 p.m. EST (9 p.m. CST, 8 p.m. MST, and 7 p.m. PST).



Within a year, German astronomer and mathematician Johann Encke calculated the comet's orbit and found it to be identical with comets observed in 1786, 1795, and 1805. Based on this orbit, Encke predicted the comet's return, and when it came back on schedule, the comet was named for him.

Comet Encke goes around the Sun once every 3.3 years, the shortest period of any comet known. And during each orbit it comes as close to the Sun as Mercury does, the second-smallest separation from the Sun of any short-period comet. Despite repeated trips around the Sun, which turns the comet's ices into gas, it seems not to have lost much of the volatile materials from its surface, because its brightness hasn't diminished since its discovery.



THE UPRAISED CLUB OF ORION is home to the long-period variable star U Orionis (RA = 5h55m49s; Dec. = 20°10'30"). Use the magnitudes shown for some nearby stars to track U Ori's brightness as it fades from its 6th-magnitude peak of late November. (This 1.5°-wide field shows south at top to match the view in an inverting telescope.)

A HOLIDAY VARIABLE

The dearth of bright planets this month allows a bright variable star to elbow its way into prominence. The star is U Orionis, a pulsating variable that peaks in brightness late this November. At that time the star should shine at 6th magnitude, though the peak brightness does vary slightly from one cycle to the next. U Ori fades slowly in December, reaching 7th magnitude by the end of the month. The star completes one cycle every 372 days on average, but it fades more slowly than it brightens so it won't reach minimum light until July. At that point U Ori shines at 12th magnitude, only about 0.4 percent as bright as at maximum.

Don't let U Orionis fool you, however. It's total luminosity doesn't change anywhere near as much as we perceive. As it pulsates, U Ori goes from being small and very red at its minimum, to larger and considerably more orange at maximum.

When U Ori is at minimum, the peak of its energy output is well into the infrared part of the spectrum, which we can't see. We see only a tiny portion of its total luminosity. As its outer atmosphere expands, it gets warmer, and the peak of its output moves nearer to the visible (although it still remains in the infrared). Thus at maximum, we see a greater portion of its luminosity and it appears considerably brighter. But the total luminosity of U Ori, added up over all wavelengths, changes only by a factor of three or four.

If you decide to make visual observations of the brightness of U Orionis, you'll need to compare its brightness with stars of known, fixed brightness. The chart above shows you where to find U Ori and gives the magnitudes of several comparison stars.

Estimating the brightness of the variable is rather simple. Let's say you observe that U Orionis is brighter than a star of magnitude 8.9, but dimmer than one of magnitude 8.3. If its brightness appears halfway between the two stars, you would estimate its magnitude at 8.6. If it's closer to the magnitude 8.3 star, then you would estimate 8.4 or 8.5. You can use this technique to follow the brightness changes of U Ori throughout December and into next year.

If you get hooked on observing the changing brightness of U Orionis and think you might like to monitor variable stars regularly, I urge you to join the American Association of Variable Star Observers. You can contact the AAVSO at 25 Birch Street, Cambridge, MA 02138. They'll send you all the materials you'll need to get started.

TELESCOPIC PLANETS

As I've already lamented, the bright planets aren't well placed for viewing this month. As December begins, **Mercury** is coming off its best morning apparition of 1993. At greatest western elongation on November 22, the innermost planet lay 12° high in the east-southeast 30 minutes before sunrise. By December 1, Mercury's altitude is 10°, so you should still be able to spot it with a little effort. On that date, the planet shines at magnitude −0.6 and displays a 5.7"-diameter disk that is 82 percent illuminated. Unfortunately, the poor seeing at such low elevations makes it difficult to view even the planet's phase. Mercury sinks rapidly into the twilight glow after the first week of December, passing 5° north of Antares on the 12th.

Venus is visible briefly in the morning sky on the first few days of December. If it weren't so bright at magnitude –3.9, you couldn't hope to spot it. On the 1st, it lies 4° above the east-southeastern horizon 30 minutes before sunrise. Its 10.0"-diameter disk appears 98 percent lit, indistinguishable from full. Mars is even worse off than Venus, remaining hidden in the Sun's glare all month.

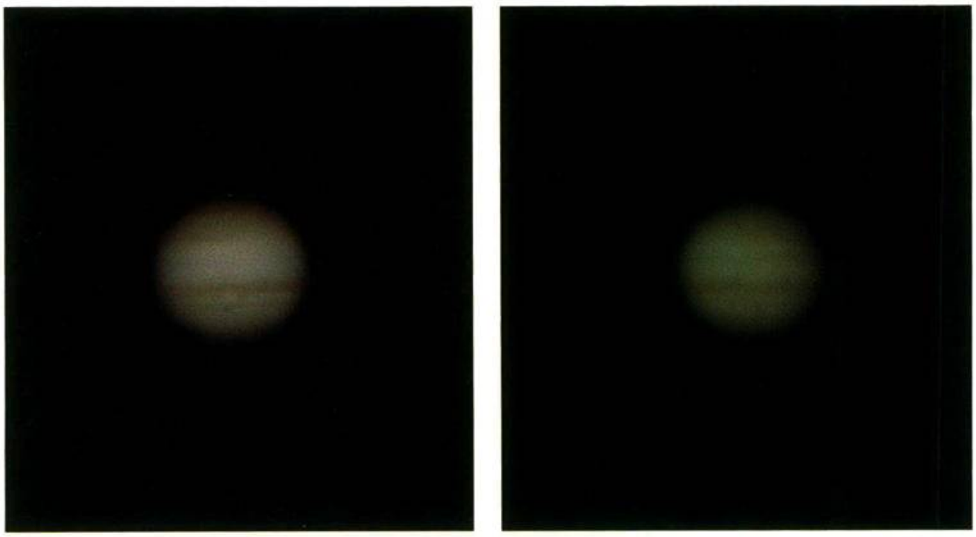
Jupiter helps make up for the hard-to-see planets in the morning sky. The giant planet reached solar conjunction on October 18 and is now high enough in the predawn sky to see quite easily. If you start viewing Jupiter around the beginning of twilight, you'll have an hour or more of good viewing. You can even observe Jupiter after sunrise. I've often found that the seeing is very steady shortly after the Sun rises.

Jupiter's South Equatorial Belt seems to have made a complete recovery after disappearing early this year. But no one knows what's in store for Jupiter in the coming months. Will we see further changes in the SEB or changes in the color of the Great Red Spot? With Jupiter's apparent diameter up to 32" this month, you can look for yourself.

This year's holiday bonus is a last good look at **Saturn** before it disappears into the evening twilight. In mid-December Saturn sets shortly after 9 p.m., so you have three hours of darkness to get your fill. But even that may not be enough time if you enjoy the ringed planet as much as I do. This month Saturn shines at magnitude 0.8 and shows a disk that measures 16" across and rings that span 37".

If you receive a telescope as a holiday gift and want to impress your relatives, first show them the Moon and then stun them with Saturn. I've never met anyone who wasn't favorably impressed by their first view of Saturn in a telescope. Who knows, maybe you'll get someone else hooked on the beauty of the night sky. ☐

Rick Shaffer is an engineer in the aerospace industry and a freelance writer living in Southern California.



Mark Schmidt

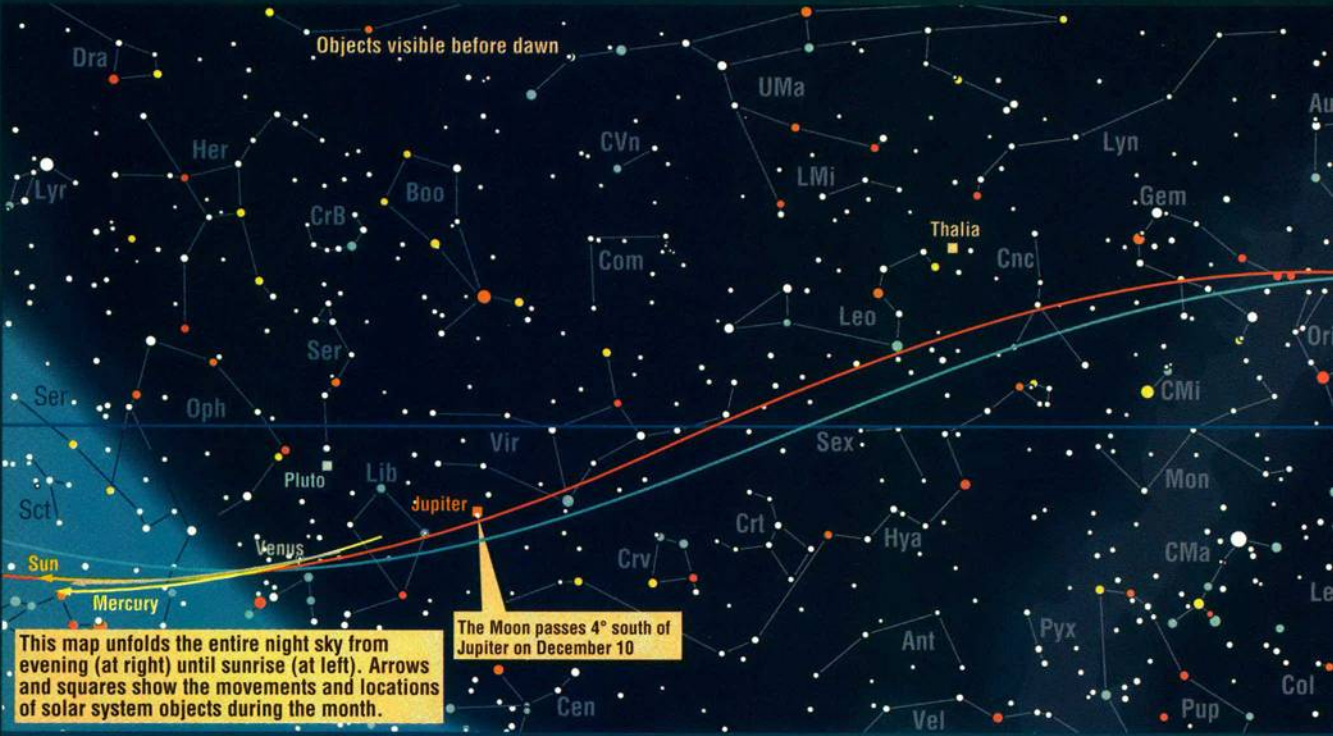
JUPITER'S SOUTH EQUATORIAL BELT faded away in early 1993 (left) but returned to view a few months later (right). To see if any changes occur as 1994 approaches, small telescope owners can use the table below as an aid when viewing the Jovian atmosphere.

GREAT RED SPOT TRANSIT TIMES

Date	Time
December 3	5:17 a.m.
December 5	6:56 a.m.
December 7	8:35 a.m.
December 10	6:05 a.m.
December 12	7:44 a.m.
December 15	5:14 a.m.
December 17	6:53 a.m.
December 19	8:32 a.m.
December 20	4:23 a.m.
December 22	6:02 a.m.
December 24	7:41 a.m.
December 25	3:32 a.m.
December 26	9:20 a.m.
December 27	5:11 a.m.
December 29	6:50 a.m.
December 30	2:41 a.m.
December 31	8:29 a.m.

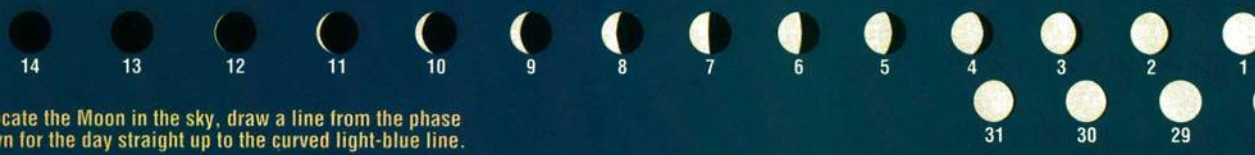
The Red Spot on Jupiter can be seen for about two hours before and after the transit times listed. All times are EST; subtract 1 hour to convert to CST, 2 hours for MST, and 3 hours for PST.

The Solar System December 1993


Objects visible before dawn
Dra
Her
Lyr
CrB
Boo
Ser
Ser
Oph
Sct
Pluto
Lib
Vir
Jupiter
Venus
Sun
Mercury
CVn
Com
UMa
LMi
Leo
Thalia
Cnc
Lyn
Au
Gem
Or
CMi
Sex
Mon
Crt
Hya
Crv
CMa
Le
Ant
Pyx
Col
Cen
Vel
Pup

This map unfolds the entire night sky from evening (at right) until sunrise (at left). Arrows and squares show the movements and locations of solar system objects during the month.

The Moon passes 4° south of Jupiter on December 10


14
13
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2
1
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30
29

To locate the Moon in the sky, draw a line from the phase shown for the day straight up to the curved light-blue line.

10"

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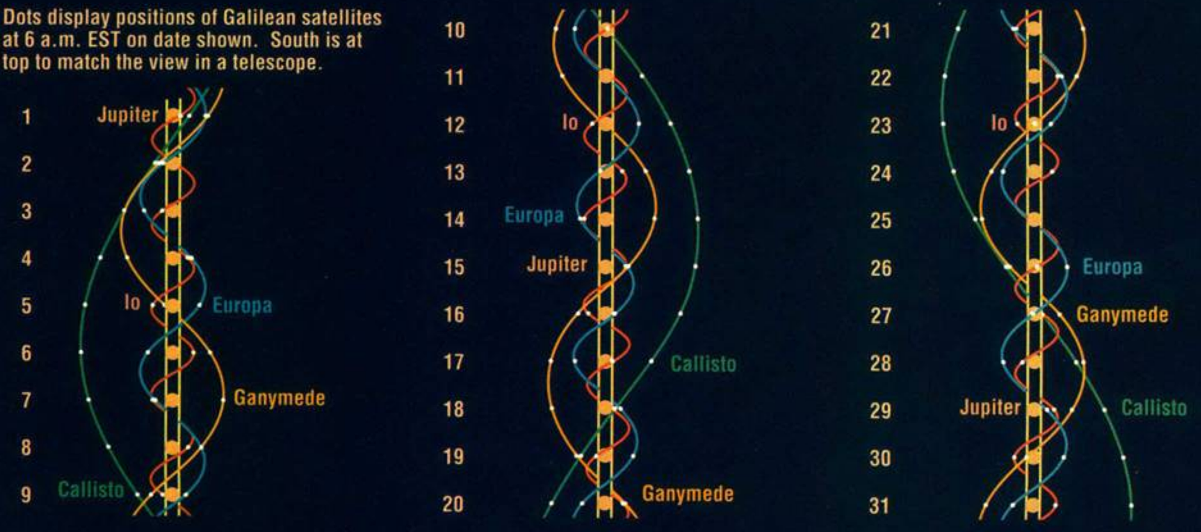
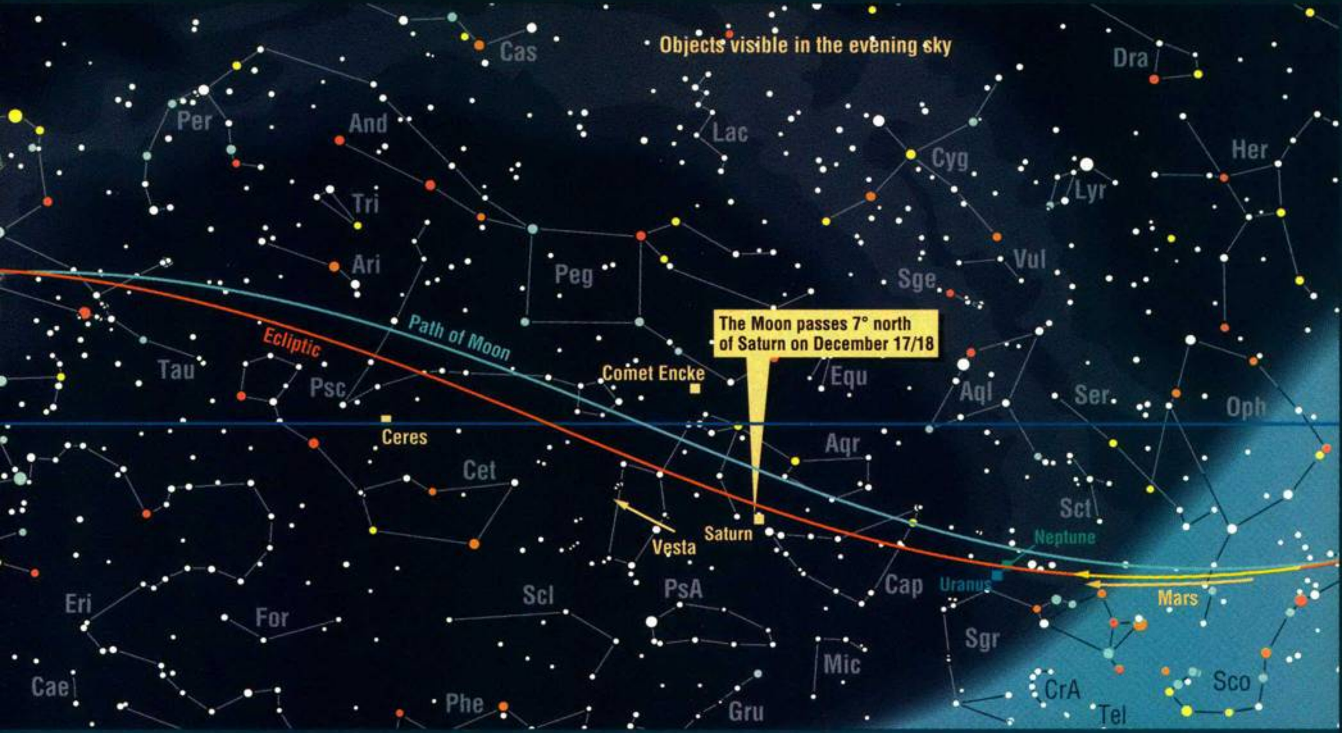
PLANETS	MERCURY	MERCURY	VENUS	MARS
Date	December 1	December 15	December 1	December 15
Magnitude	−0.6	−0.7	−3.9	1.3
Angular Size	5.7"	4.9"	10.0"	3.8"
Illumination	82%	96%	98%	100%
Distance (AU) from Earth	1.187	1.377	1.664	2.440
Distance (AU) from Sun	0.389	0.451	0.723	1.458
Right Ascension (2000.0)	15h17.2m	16h42.8m	15h42.0m	17h43.8m
Declination (2000.0)	−16°26'	−22°14'	−18°48'	−24°05'

Jupiter's Moons



Dots display positions of Galilean satellites at 6 a.m. EST on date shown. South is at top to match the view in a telescope.


Objects visible in the evening sky

The Moon passes 7° north of Saturn on December 17/18

Cas
Dra
Per
And
Lac
Cyg
Lyr
Her
Tri
Ari
Peg
Sge
Vul
Path of Moon
Ecliptic
Tau
Psc
Comet Encke
Equ
Aql
Ser
Oph
Ceres
Aqr
Cet
Sct
Saturn
Vesta
Neptune
Uranus
Cap
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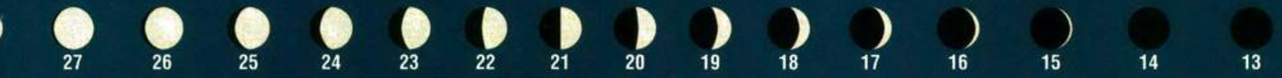
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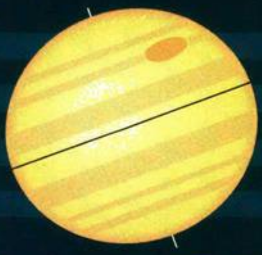
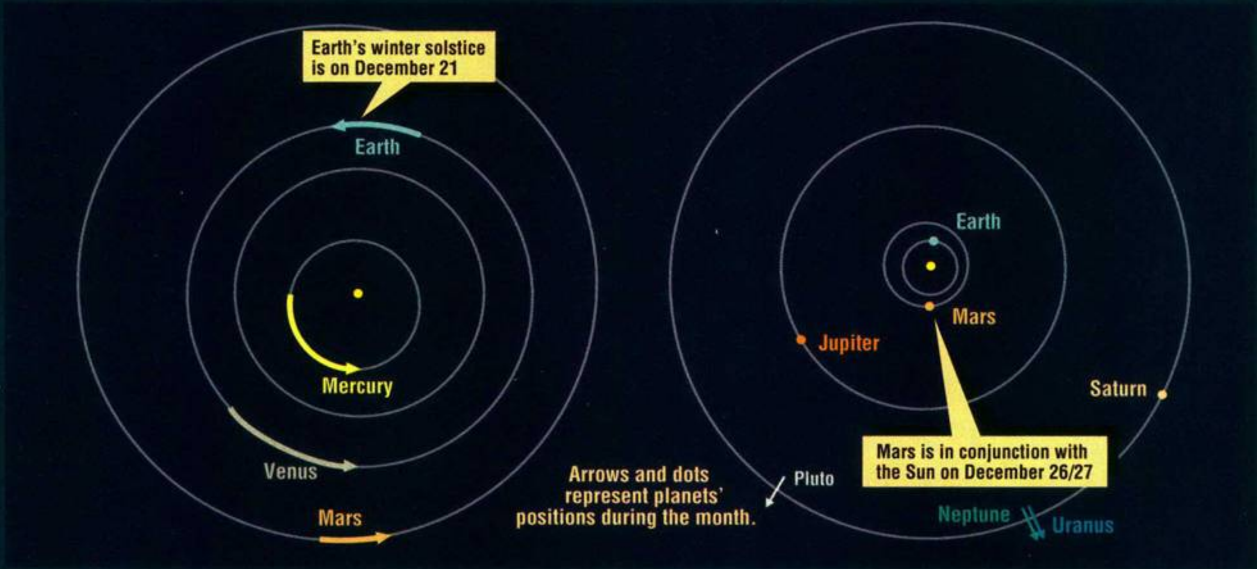


JUPITER	SATURN	URANUS	NEPTUNE	PLUTO
December 15	December 15	December 15	December 15	December 15
−1.8	0.8	5.8	8.0	13.8
32.4"	16.2"	3.4"	2.2"	0.1"
100%	100%	100%	100%	100%
6.082	10.198	20.497	31.056	30.611
5.446	9.783	19.630	30.181	29.760
14h20.1m	21h53.5m	19h29.8m	19h25.9m	15h49.8m
−12°48'	−14°20'	−22°18'	−21°21'	−6°02'

The Planets in Their Orbits


Earth's winter solstice is on December 21

Mars is in conjunction with the Sun on December 26/27

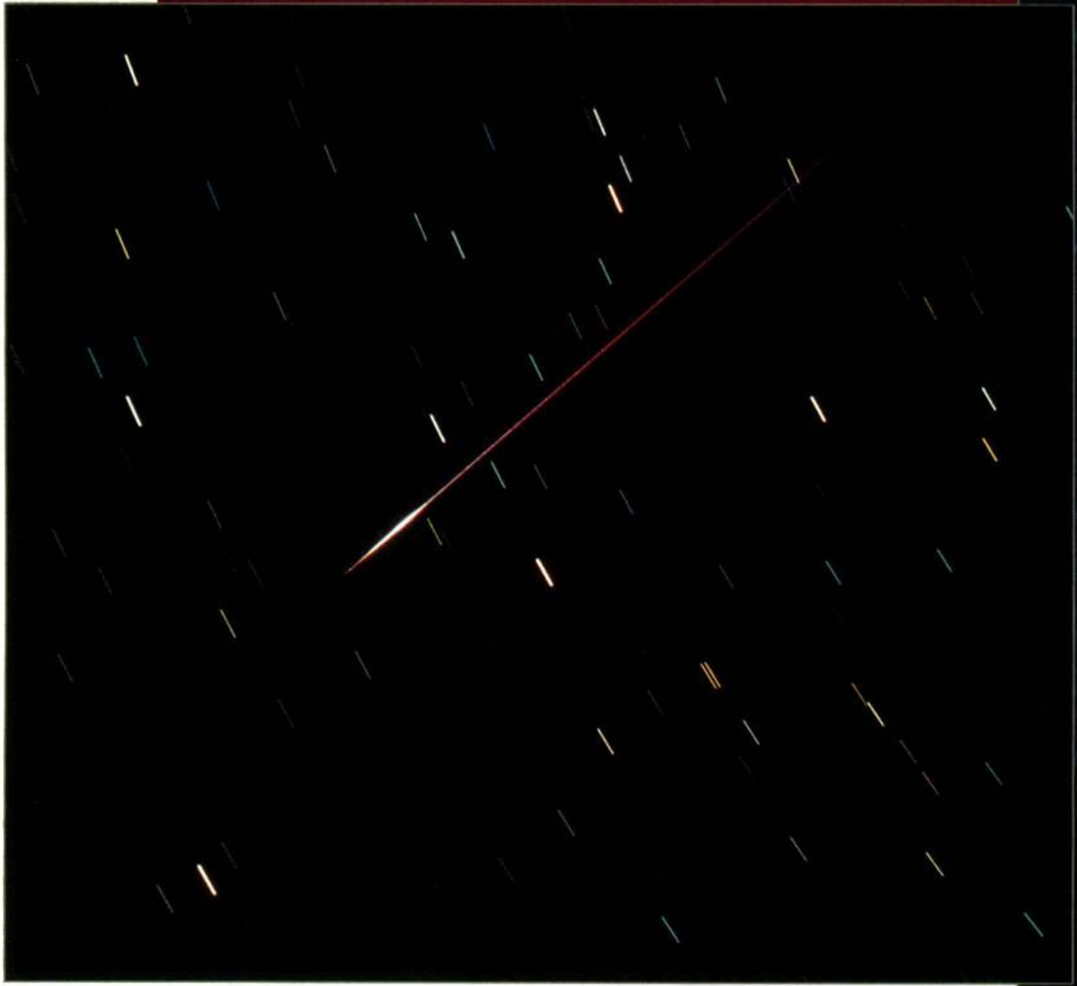
Arrows and dots represent planets' positions during the month.

Earth
Mercury
Venus
Mars
Earth
Mars
Jupiter
Saturn
Pluto
Neptune
Uranus

THE STORM THAT GOT AWAY

The predicted August meteor "storm" did not materialize. Nevertheless, observers witnessed one of the best displays of Perseid meteors in recent years.

by David J. Eicher



▲ **AN UNUSUALLY REDDISH PERSEID**

Photo by James Glenn Pearson

A PERSEID STREAKS THROUGH ANDROMEDA ►

Photo by Barry E. Levin

The jury was in by 10 p.m. on Wednesday, August 11, 1993. "Reports from skywatchers around the Milwaukee area indicate no great meteor activity," said a down-in-the-dumps television anchor. Even before the predicted peak of this year's Perseid meteor shower (in the early morning hours of August 12), the media had already built a story around the meteors and then knocked it down.

The possibility of a surge of activity did exist for this year's event, based on the 1992 return of the meteor shower's progenitor comet, Swift-Tuttle. The idea was that the comet would deposit fresh clouds of material so that when we again passed through its orbit, the sky would blaze with meteor flashes. Some scientists took the idea seriously: NASA delayed a space shuttle flight due to the possible danger of impacts, and a telegram from the International Astronomical Union raised the possibility of seeing meteoroids smack into the Moon as they produced flashes at impact.

As it turned out, no great meteor flurry occurred. But what got lost was that this year's Perseid meteor event was a particularly fine "normal" shower that produced an abnormally high number of bright fireballs — very bright meteors that typically burst apart visibly or leave a glowing "train" in the sky lasting several seconds. Anyone who has seen a meteor shower before knows they witnessed an excellent one this summer, one with the Moon out of the way and with 60 to 110 meteors visible each hour.

The observing reports began streaming into ASTRONOMY's offices by e-mail and fax the next day, even as Earth remained in the outer parts of the Perseid meteor stream. "We observed and recorded nearly 800 meteors between 8 p.m. MST on

▲ **A MAGNITUDE –2 FIREBALL**

Photo by Jerry Schad

◄ **A TYPICALLY FAINT PERSEID**

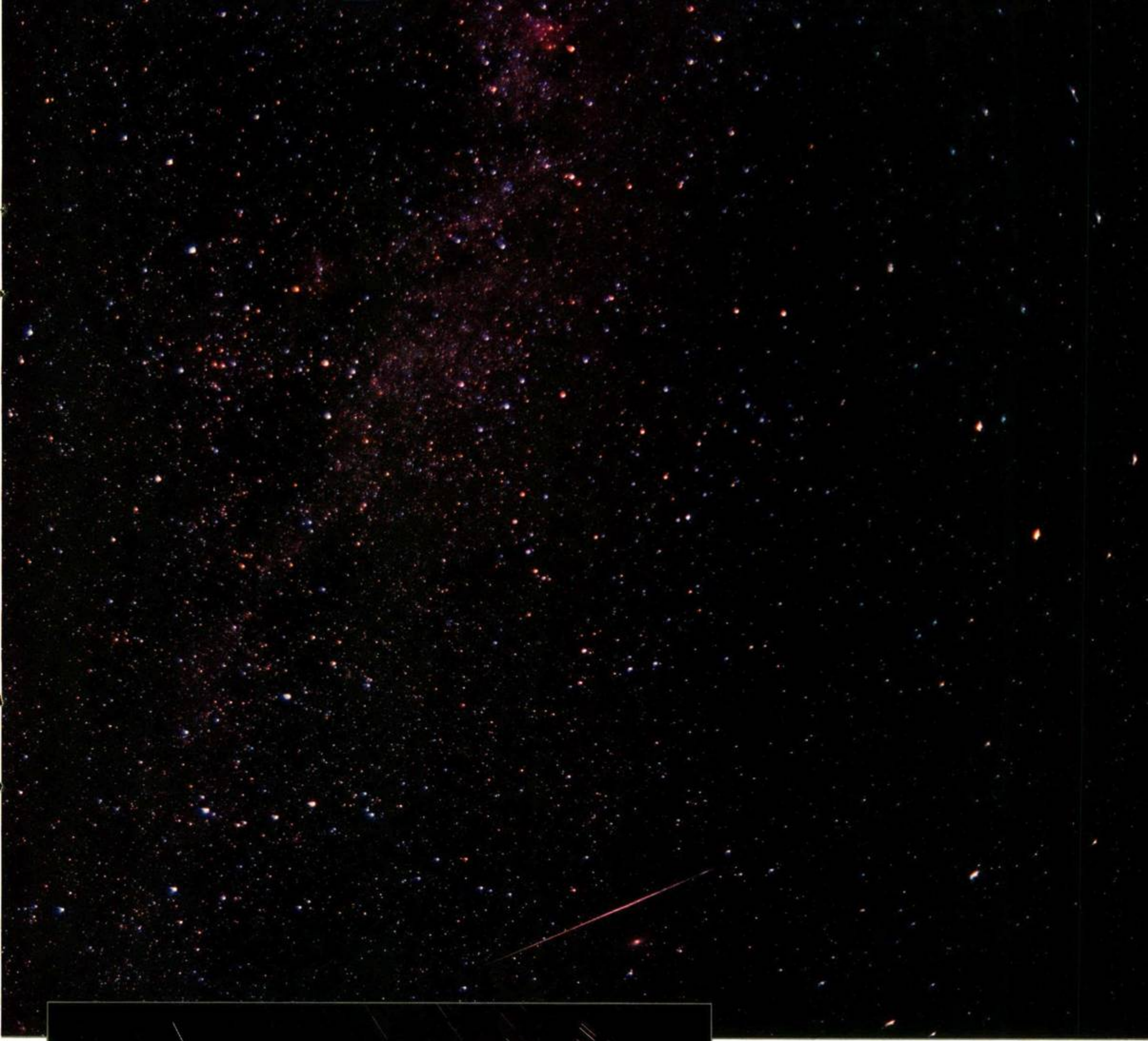
Photo by Wallace D. Baldwin

August 11 and 3 a.m. the following morning," says Frank Kraljic of Scottsdale, Arizona. Thirty skywatchers from the East Valley Astronomy Club viewed the shower 60 miles east of Phoenix. "I recorded about 300 myself," Kraljic remarks. "The average per hour was 113 under dark skies until the Moon rose over the mountains."

Rob Donner of Goleta, California, observed the shower from the cliffs at Isle Vista. "For the first time in five years we had favorable weather for a Perseid shower," reports Donner. "Over a three-hour period beginning at 10:30 p.m. PDT on the 11th, I spotted 124 meteors. Over two-thirds of them left trains, and three were brighter than magnitude –4. Of the three, two seemed to explode before fading. Several meteors traversed more than 20° of sky. All appeared to be moderately fast, yellow in color, and relatively bright."

Members of the Society of Low Energy Observers in Memphis had similar results. "About 30 of us traveled to Stanton, Tennessee, and began viewing at 8:45 p.m. CDT on the 11th," says Edwin Faughn, president of the group. Faughn and friends counted 250 meteors over the following four hours. "A surge in the activity appeared around 10 p.m.," he says, "and lasted for about 45 minutes during which we saw 60 meteors." The Tennessee observers estimated that 35 to 40 percent of the meteors they observed were fireballs. They recorded a spectrum of colors in some of the bright meteors, including blues, greens, whites, and orange-reds. Many of the meteors streaked across Cygnus. Ursa Major and Capricornus were also frequent areas of meteor activity. "All in all, this was the most spectacular meteor shower we've seen," says Faughn.

Others watched the shower under less-favorable sky conditions. Earl W. Phillips Jr., of Columbus, Ohio, forwarded his "meteor trickle report." It was supposed to be a meteor shower report, but intermittent clouds and heavy haze reduced the number of meteors visible. Phillips



▲ **SCOOTING PAST ANDROMEDA'S GALAXY**

Photo by Dan Schechter

◄ **FROM BIG DIPPER TO HORIZON**

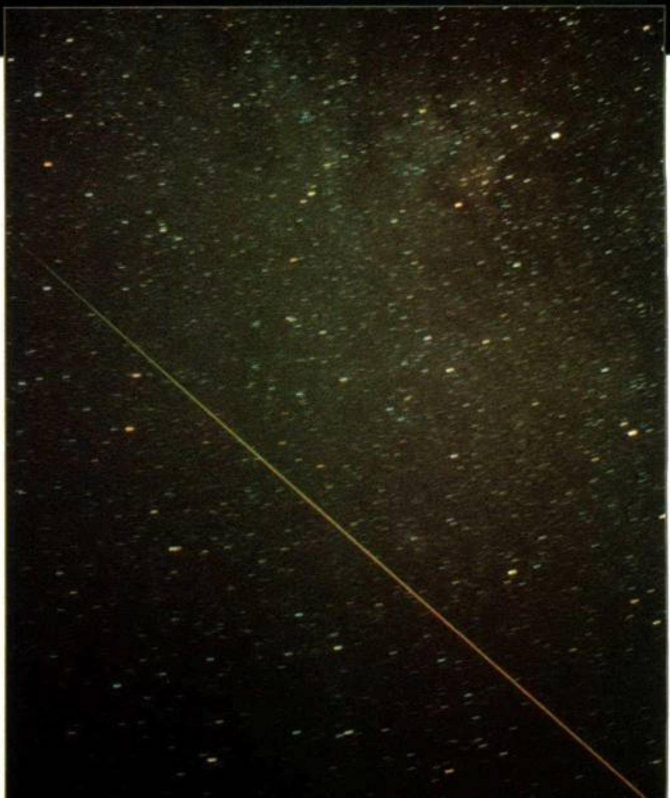
Photo by Robert May

▲ **MAGNITUDE –1 PERSEID IN URSA MINOR**

Photo by Graham Sinagola

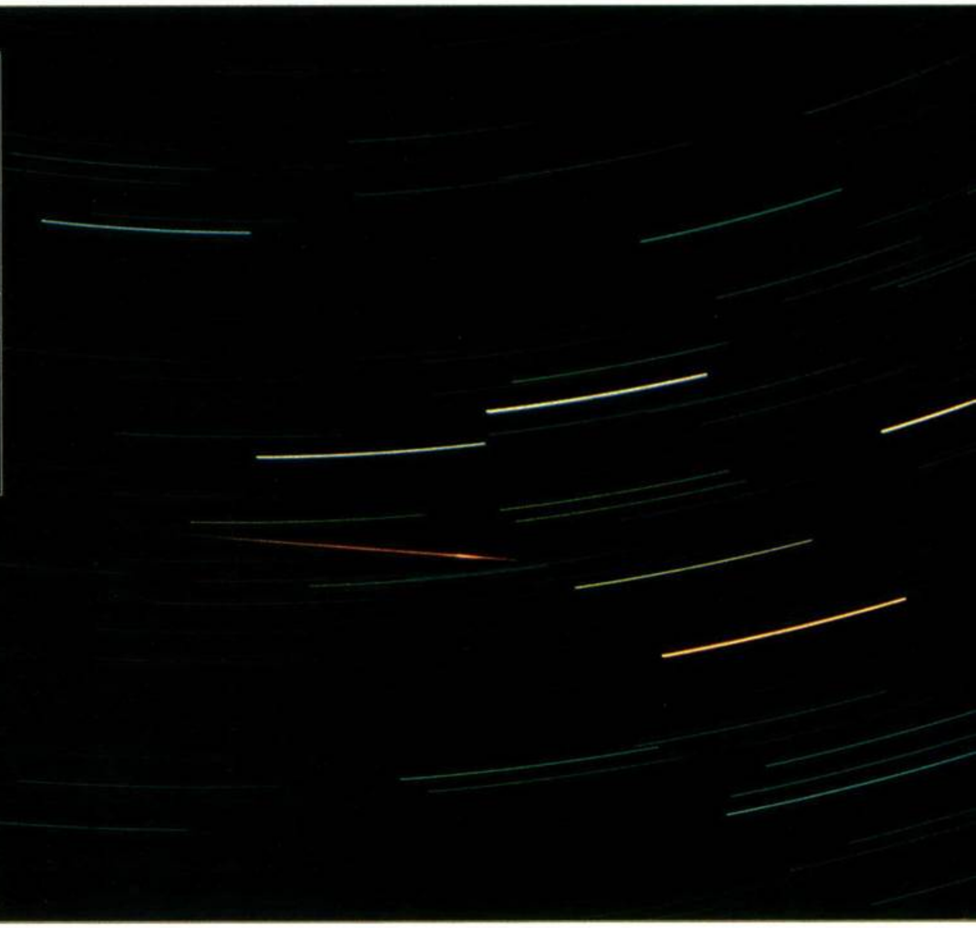
LONG TRAIL CUTS THROUGH CYGNUS ►

Photo by George W. Fleenor



▲ **METEOR ACROSS THE MILKY WAY**

Photo by Wallace D. Baldwin



A FIREBALL IN CASSIOPEIA ►

Photo by Brian W. Homme

and students in his astronomy class joined members of the Westerville Astronomy Interest Group to view the shower from the Alum Creek State Park. "Despite the limiting magnitude of 3 and average sky blockage by clouds of 35 percent, we still saw meteors," reports Phillips. "Quite a few spectacular meteors were visible, mostly bright yellowish streaks that crossed much of the sky. Some flashes that appeared like lightning were actually Perseids peeking through clouds."

Mike Boschat of Halifax, Nova Scotia, attempted to outrun clouds by driving some 75 miles away from the socked-in Halifax area. With a partly cloudy sky and a limiting magnitude of 6 where it was clear, Boschat spotted 27 meteors in $2^{1}/_{2}$ hours. "The best one was a magnitude –4 bluish streak that sped through the clouds and produced a halo of sorts," he says. "I observed many bright meteors between magnitudes –1 and –3, most of them glowing yellow or blue in color."

Canadian observer Terry Dickinson of Yarker, Ontario, also had clouds to contend with. "Conditions were far from ideal, but not a complete washout," he says. "I was clouded out entirely between 11:15 and 11:50 p.m. EDT and again from 12:30 to 2 a.m. After 2 a.m. haze got worse and I gave up. But during the periods of partially clear skies, I saw about 20 meteors per hour, including a number of bright ones."

Fellow Canadian Ken Hewitt-White of Naramata, British Columbia, had much better conditions from the summit of Mt. Kobau. "The average hourly rate this year was 63," asserts Hewitt-White. "A fine shower, but I've seen much better ones, including the 1988 display." During evening twilight he spotted quite a few faint meteors and for a time had the impression of viewing the "tail end of the predicted meteor storm." Later, however, Hewitt-White found the rate rose slowly as the radiant rose. The majority of the meteors appeared yellow or orange, he says, and most of the bright meteors were visible relatively early in the evening.

"There was no storm here!" according to David York of Abiquiu, New Mexico. Blessed with terrific conditions — photometric skies, a clear 360° horizon, and a limiting magnitude of 7.0 — York was in a perfect spot to judge the activity. "In two hours of observing I watched 116 Perseids and 34 sporadics streak overhead," he says. "I also saw some odd meteors: six sporadics seemed to come from a point north of Cassiopeia. At one point I saw three bright meteors in rapid succession and then three more spread over the next half hour. It was a good shower, a good year."

Before the 1993 storm failed to occur, two British professional astronomers were predicting that the 1994 shower might be the really active one. Zidian Wu and Iwan Williams of Queen Mary and Westfield College in London suggest that Earth will encounter the thickest part of Swift-Tuttle's cloud of debris next summer.

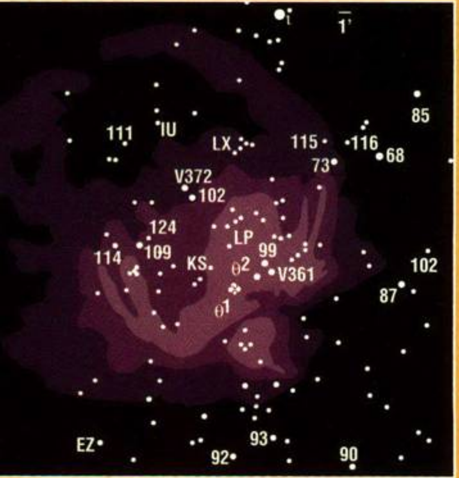
Based on the comet's 1862 apparition, Wu and Williams' research shows Earth began to encounter new pockets of dust (ejected by the comet in 1862) several years ago. This ties in with the rise in numbers of Perseid meteors observed over the past several years.

So another year's worth of publicity may surround the Perseid shower. Next year the activity should be nicely visible except that meteors in the evening will be harder to spot because of a nearly First Quarter Moon in the sky. But during the morning hours, when Earth's night side rotates head on into the meteor stream, we'll again have a chance at seeing a superb normal display. Who will be the first to suggest the word storm? ☐

ORION'S SHOWPIECE NEBULA

Explore the Orion Nebula, a wonderland visible to the naked eye.

by David J. Eicher



Winter brings it back every year. It's the thing — the fuzzy thing. The thing in Orion that elicits the same words every winter season: "There it is — Wow! Omigod!" The thing is the Orion Nebula (also known as M42, NGC 1976), one of the sky's prettiest attractions and a perennial favorite of budding skywatchers. The powerful lure of this nebula is twofold.

People who look at deep-sky objects are fascinated by two primary realities. The first is the ability to see a distant object and the comfortable knowledge of what that fuzzy thing is. Deep-sky observers know the Orion Nebula as more than a fuzzy smudge. They know it as a vast glowing gas cloud and star factory peppered with numerous newly formed suns and spanning 30 light-years. The cloud lies at a distance of 1,700 light-years from us.

The second fascination for deep-sky watchers comes thanks to a telescope. These instruments of glass and wood show us enough detail to make deep-sky objects beautiful. The Orion Nebula is an outstanding example of such beauty. Armed with a 3-inch telescope on a moonless night you can see considerable detail in this object. The brightest part of the nebula surrounds the multiple star Theta^1 (θ^1) Orionis, called the Trapezium because its four components are arranged in a trapezoidal shape. Northwest of this central group of stars lies the bright double Theta^2 (θ^2) Orionis. Other bright stars are scattered throughout the field, many of which are variable in their light output. Some of these variable stars are identified by letters in the diagram, while steady comparison stars have magnitudes provided in tenths.

But the real beauty of the Orion Nebula stands out through the extent of its nebulosity, which covers more than 1½° of sky, or three diameters of the Full Moon. The nebulosity surrounding Theta^1 fans outward to the west and north. A bright arc of light curves through the gap between Theta^1 and Theta^2 Orionis. Another conspicuous feature prominently marks the area east of Theta^1, but it marks it by darkness rather than light. It is the "Fish's Mouth," a wavy channel of dark nebulosity visible in any telescope.

A larger telescope brings out levels of ever fainter nebulosity. A 6-inch scope reveals an envelope of light surrounding the bright, inner portions that extends far south, east, and west of the Trapezium area. On dark nights you'll see huge fans of nebulosity arcing southward on both the eastern and western sides of the object. It's a sight of almost indescribable beauty, the faint nebulosity glowing in electric gray-green and studded with bright points of white, blue-white, and orange-red starlight.

The Orion Nebula is a killer. A careful view of this object undermines the notion that photography captures immeasurably more than the eye can see. On the contrary, an hour or two spent watching the Orion Nebula shows that the subtle features of this grand object are best visible with the eye, for it shows detail that film or electronic images cannot hope to capture. That's a powerful truth you will arrive at this winter when you stand out under that spellbinding fuzzy thing in Orion.

Jack Newton

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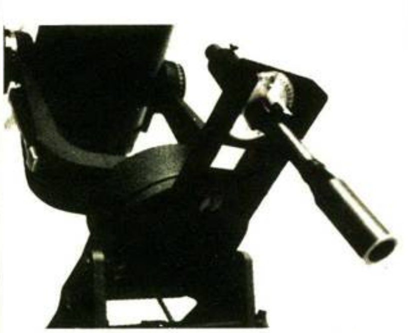

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ORION'S LOW-COST DOBSONIANS

Field tests of two of Orion's new Dobsonian reflectors show that these entry-level telescopes deliver excellent views at affordable prices.

by Alan Dyer

Many aspiring backyard astronomers today are looking for a quality telescope that will not require them to spend a great deal of money. Orion Telescope Center has several new telescopes aimed at just such a buyer. I tested two of Orion's new Deep Space Explorer series and discovered high-performance yet highly affordable telescopes.

John Dobson's Revolutionary Design

If you've seen "The Astronomers" TV series or watched Johnny Carson faithfully, you've seen John Dobson. A man with a mission to promote astronomy, Dobson revolutionized amateur astronomy by popularizing the style of telescope mounting that now carries his name.

The Dobsonian mount is simplicity itself. The telescope tube rests in a wooden cradle that sits on a swiveling base. Just swing the telescope to the area of sky you want and let go. The scope stays put. Following

ORION
DEEP SPACE
EXPLORER

SETTING UP A DEEP-SPACE EXPLORER requires no more than dropping the tube onto the cradle. The 6-inch (left) and 8-inch models have tubes roughly the same length.

ASTRONOMY: All photos by James Forbes

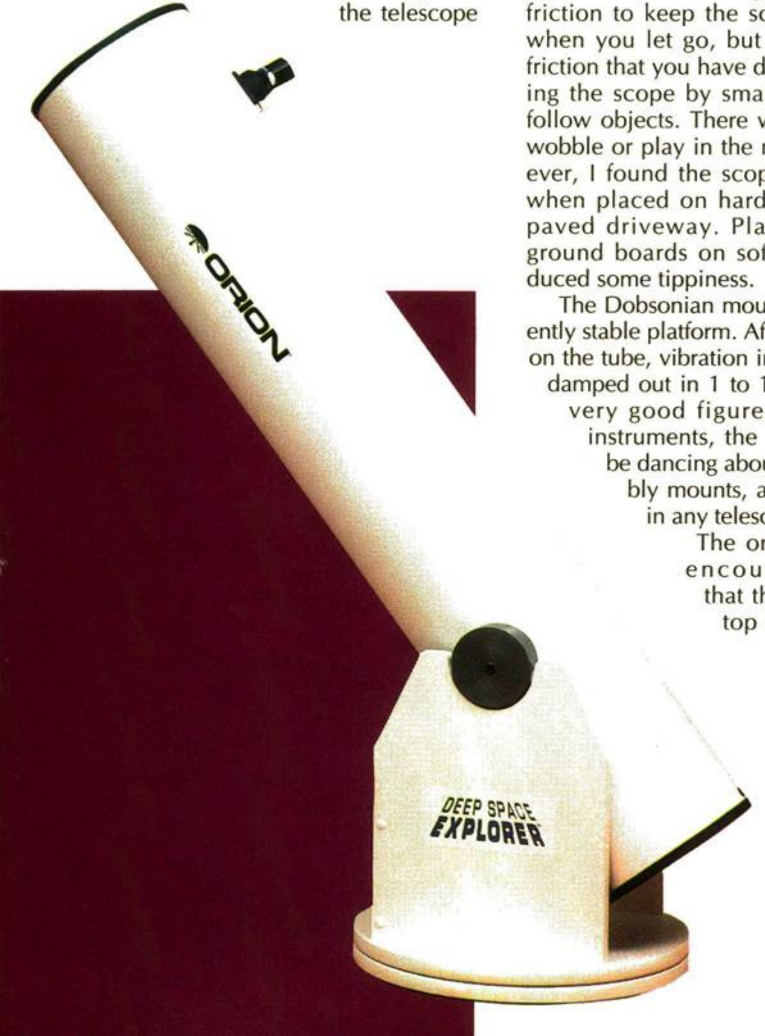
objects across the sky requires gently nudging the scope every few seconds, an action that Dobsonian owners find quickly becomes second nature.

The Dobsonian mount is inexpensive and easy to make. Many budget-conscious amateurs handy with hammer and saw fashion this type of mount themselves. Previously, the only commercial manufacturer of low-cost Dobsonians was Coulter Optical Co. (A review of Coulter's 8-inch f/4.5 model appeared in the December 1991 issue.) Now the Orion Telescope Center has introduced a new series of commercially made Dobsonians.

Orion's Deep Space Explorer series features four models: portable 6-inch f/8 and 8-inch f/6 telescopes, a moderate-aperture 10-inch f/5.6, and a large 12.5-inch f/4.8. All are classic Newtonian reflectors, telescopes that use mirrors rather than lenses to collect and focus light. The size in inches refers to the diameter of the main concave mirror located at the bottom of the tube. The larger the mirror, the brighter and sharper the images will appear.

The f/ratio number, such as f/8, relates to the focal length of the telescope — in effect, the distance from the main mirror to the eyepiece at the top of the tube. The 6-inch f/8, for example, has a focal length eight times the diameter of the mirror, or 48 inches, making the tube about 4 feet long.

Using units supplied by Orion, I tested the two smallest and most affordable models, the 6-inch f/8 ($299) and the 8-inch f/6 ($399), telescopes likely to be popular among first-time buyers or families wanting to tour the universe on an economy ticket.



The Mounting

Orion has done a fine job executing the classic Dobsonian design. The up-down, or altitude, motion uses two 4-inch-diameter PVC plastic cylinders bolted to either side of the tube as the axis. These rest in the mount's cradle boards and ride on Teflon pads (two per side). The side-to-side, or azimuth, motion uses three Teflon pads fastened to the stationary ground board. The mount rests on these pads and swivels about a central bolt sheathed in a plastic sleeve.

The motions of both telescopes were extremely smooth. Both axes exhibited just the right amount of friction to keep the scope in place when you let go, but not so much friction that you have difficulty nudging the scope by small amounts to follow objects. There was almost no wobble or play in the mounts. However, I found the scopes work best when placed on hard ground or a paved driveway. Placing the flat ground boards on soft grass introduced some tippiness.

The Dobsonian mount is an inherently stable platform. After a sharp rap on the tube, vibration in these scopes damped out in 1 to 1½ seconds, a very good figure. With these instruments, the images won't be dancing about due to wobbly mounts, a valuable trait in any telescope.

The only problem I encountered was that the 6-inch was top heavy. When aimed below an altitude of 45°, the scope tended to sink by itself when equipped with the normal 25mm eyepiece. The additional weight of a finderscope at the top of the tube would have made the unit I tested impossible to use. Our test unit needed extra weight added to the back of the telescope to rebalance the scope. Tim Gieseler of Orion told us that this should not have been the case and that the unit we had received had been assembled with the altitude bearings bolted too far down the tube.

The 8-inch balanced properly right from the start. It handled even a heavy 22mm Panoptic eyepiece or a small finderscope plus a regular-weight eyepiece, although the combination of a heavy eyepiece and a finderscope would require adding extra weight to the rear of the scope. Orion offers optional counterweights that screw onto the bottom of the Explorer's mirror cells for this purpose.

My other suggestion is that a handle or hole cut into each of the vertical cradle boards would have been welcome. While the 6- and 8-inch telescopes are not heavy, it is still hard to get a grip on the mounts to move them about.

The Optics

Both telescopes produced clean, sharp images of stars and planets. Saturn was a delight, with the Cassini division in the rings clearly visible, along with tan-colored cloud belts on the planet itself. On several nights I simply stopped worrying about testing the telescopes and just sat back and enjoyed the view. When that happens, I know the telescope has passed with flying colors.

On examining stars at high power (the telling "star test") both scopes showed dim stars as tiny, cleanly defined disks of light (the Airy disk) surrounded by a faint ring of light (the first diffraction ring), just as good optics should. Bright stars were not as cleanly defined and showed more fuzz around in-focus star images.

When thrown out of focus, all stars showed nearly identical diffraction patterns on either side of focus, an indication that image-blurring spherical aberration was negligible. Out-of-focus patterns did show a slight bump or flare (depending on which side of focus I was on) due to warm air currents' creeping up the inside of the tube wall. It took 30 to 60 minutes for the worst of these image-degrading tube currents to disappear. As with every telescope, letting it cool down is critical before performing star tests.

Even after cool-down, I fully expected to see a slight level of astigmatism, a common flaw in optics. This aberration can ruin the sharpness of star and planet images. You can check for astigmatism by throwing a star just slightly out of focus at very high power. If the out-of-focus pattern turns elliptical and if the ellipse flips 90° when you rack to the other side of focus, the scope is astigmatic. The flaw could be inherent in the optics or could be due to the optics' being physically warped by whatever mechanism holds the lenses or mirrors. But in the case of the Deep Space Explorers I was pleased to find absolutely no trace of astigmatism.

In short, these were excellent mirrors. Orion promises that all Deep Space Explorer mirrors are "1/8-wave." When I inquired about this specification, Tim Gieseler explained that this figure referred to the peak-to-valley accuracy of the mirror surface itself. In other words, the total deviation from the ideal shape of the mirror when measured from the top of the highest "hill" on the surface to the bottom of the deepest "dip" is promised to be no more than 1/8 of a wavelength of light, although Orion doesn't specify what wavelength they are using as a standard.

But any error on a mirror's surface produces double the error in the wavefront of the light reflected off that surface. So a mirror with a 1/8-wave surface produces a reflected wavefront with a 1/4-wave accuracy. While this sounds worse, it is actually a superb level of performance. In fact, a mirror with a wavefront error of 1/4-wave earns the term "diffraction limited." This means the quality of the image is affected more by the natural effects of the diffraction of light waves than it is by the effects of any optical flaws that may be present.

Verifying the wavefront accuracy of optics requires sophisticated tests on a device called a laser interferometer. But the fact that during star tests the Explorers' optics exhibited a clean Airy disk and inner diffraction ring with little sign of common aberrations indicated to me that these scopes were performing to a high standard. If these were not 1/4-wavefront-error scopes, they were certainly close to it. This is an outstanding level of optical quality from telescopes this affordable.

Telescope makers will point out that the Explorers' mirrors are made

A FINELY THREADED HELICAL FOCUSER supports a single-vane spider that in turn holds the small secondary mirror. The focuser and spider are simple but work well.

SEPARATING THE MOUNT from the ground board (something you normally never need do) reveals the three Teflon pads and plastic-sleeved bolt that provide the smooth azimuth motion.

DEEP SPACE EXPLORER

THE MIRRORS ARE GLUED onto a piece of particle board with dabs of silicone. Three spring-loaded bolts pass through a lead counterweight to provide collimation adjustments accessible from the back of the telescope.

of plate glass and not low-expansion Pyrex, the material traditionally preferred for telescope mirrors. Pyrex mirrors will not change shape as readily as the air temperature falls, which helps ensure consistent image quality no matter how warm or cold the night.

The reason for not using Pyrex is cost. Gieseler explained that the plate glass is easier and quicker to grind and polish, a key factor in keeping these telescopes affordable. In actual tests I found little evidence for any deterioration of the image due to temperature effects. However, I field-tested the scopes on summer nights when the temperature was 50 degrees Fahrenheit or warmer. Cold nights might show more effect, but I suspect that any "fuzzing" of the image from changes in the mirror figure (due to added spherical aberration) would be slight and apparent only to well-trained eyes. In these entry-level scopes, the use of plate glass appears to be a fair trade-off.

Fittings and Features

The finish of these scopes is not fancy but is clean and durable. The mounts are made of particle board covered with white laminate. The tubes are made of Sonotube, a cardboard material wrapped in coated white paper. Sonotube is an economical but sturdy choice that has been used by thousands of telescope makers for their homemade scopes. Don't worry — these tubes will not turn into a soggy mess on dewy nights. Rubber end rings protect the tube ends from bumps.

The focuser accepts 1¼-inch-diameter eyepieces and is a helical style with about 1¼ inches of focus travel. The fine helical threads provide smooth and precise focus adjustments for such a low-cost focuser. The focuser was at a convenient height and angle for seated observing.

The standard eyepiece included with all the Explorer scopes is a 25mm Plössl from Orion's new Sirius line of low-cost eyepieces. The Sirius eyepieces provided high-contrast, ghost-free images. It's great to see such a fine-quality eyepiece included as standard equipment on any entry-level scope, but I recommend purchasers budget for a second, higher-power eyepiece such as a 10mm or 7.5mm Plössl.

The other optional item I found to be an absolute necessity is some style of finderscope, either a 6x30 finder or a Telrad, a clever device that projects a red bull's eye onto the sky to help you aim the telescope. Without a finder, locating objects with these telescopes can be a frustrating exercise. To add a finder, you will have to drill holes in the tube.

To sum up, I was impressed with the Deep Space Explorers. Orion has succeeded in producing what many backyard astronomers have been waiting for — affordable, easy-to-use telescopes with sharp optics and sturdy mounts. If that's what you're looking for, investigate the Deep Space Explorers. □

ORION DEEP-SPACE EXPLORERS

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Tube diameter	7.5" O.D.; 7" I.D.	9.5" O.D.; 9" I.D.
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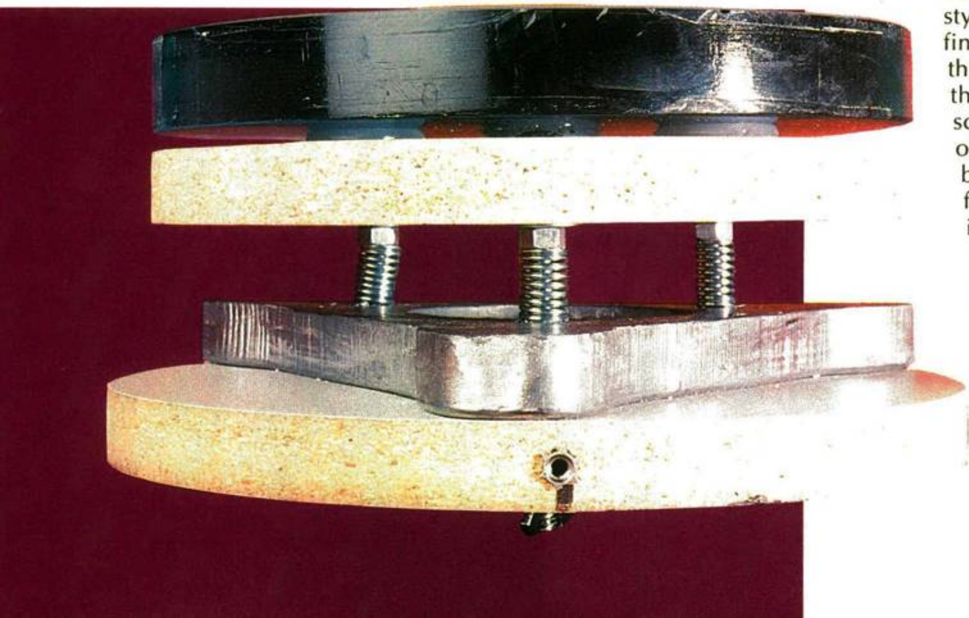
Catalog price	$299 + $39 shipping	$399 + $49 shipping
Warranty	1 year	1 year

Orion Telescope Center, 2450 17th Avenue, P.O. Box 1158A, Santa Cruz, CA 95061-1158, (800) 447-1001; in California: (800) 443-1001. Also available: 10-inch ($599) and 12.5-inch ($769) models.



CATCH THE GEMINID METEOR SHOWER

NAKED-EYE OBSERVING

Be sure to watch for Geminid meteors the night of December 13/14. A New Moon promises dark skies for this prolific shower.

by Mark J. Coco

Terence Dickinson

A GEMINID STREAKED below Mars and the Pleiades during the 1990 shower. The absence of the Moon from the night sky means you should see lots of meteors this year.

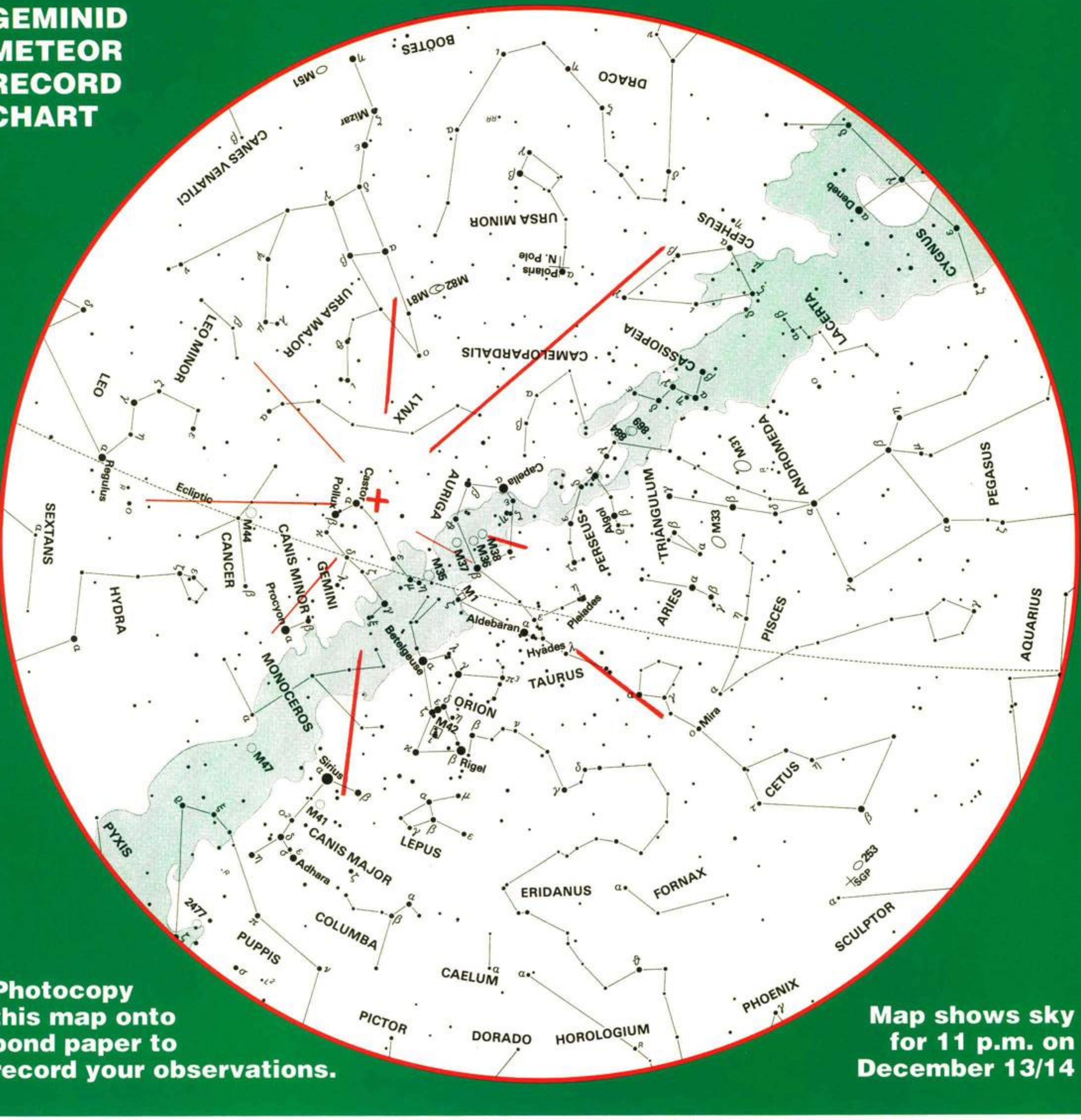
Normally, the best meteor display during a year is the Perseid shower in August, right? Nope. December usually offers the finest spectacles of "shooting" or "falling" stars — the Geminid meteor shower. Many backyard astronomers pass up this shower because the crisp winter nights deter all but the most ardent observers.

Don't let the cold weather stop you from observing the shower this year. Bundle up and lie back comfortably in a lounge chair while wrapped in a sleeping bag. A thermos full of your favorite hot beverage will complete your winter observing survival kit. Your reward for braving the elements will be lots of meteors — in fact, more than usual because you'll be able to see faint ones in the dark skies presented by the New Moon.

Meteors are particles the size of sand grains that burn up as they enter Earth's atmosphere. On any clear, moonless night when there is no meteor shower you can expect to see five to ten meteors per hour. These are "sporadic" meteors, which come from no preferred direction and arise from chance encounters with material orbiting the Sun. Meteor showers like the Geminids occur when Earth passes through a particle stream.

The concentration of particles in a meteor stream increases the number of meteors seen per hour and makes them appear to originate from a single point in the sky known as the radiant. This appearance is an optical illusion, however. Just as the parallel tracks of a

GEMINID METEOR RECORD CHART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Mizar
DRACO
CANES VENATICI
URSA MINOR
N. Pole
Polaris
Deneb
CEPHEUS
CYGNUS
M82
M81
URSA MAJOR
LEO MINOR
CAMELOPARDALIS
CASSIOPEIA
LACERTA
LEO
LYNX
869
884
M31
ANDROMEDA
PEGASUS
Regulus
Ecliptic
Castor
Pollux
AURIGA
Capella
TRIANGULUM
SEXTANS
M44
CANCER
CANIS MINOR
GEMINI
M35
M37
M36
M38
PERSEUS
Algol
M33
ARIES
PISCES
HYDRA
Procyon
M1
Aldebaran
Pleiades
Hyades
TAURUS
AQUARIUS
MONOCEROS
Betelgeuse
ORION
M42
Rigel
Mira
M47
Sirius
CETUS
PYXIS
M41
Adhara
CANIS MAJOR
LEPUS
ERIDANUS
FORNAX
253
SGP
SCULPTOR
2477
PUPPIS
COLUMBA
CAELUM
PHOENIX
PICTOR
DORADO
HOROLOGIUM

Photocopy this map onto bond paper to record your observations.

Map shows sky for 11 p.m. on December 13/14

railroad or the sides of a highway seem to come together in the distance, the parallel paths of meteors make their trails appear to come from one point.

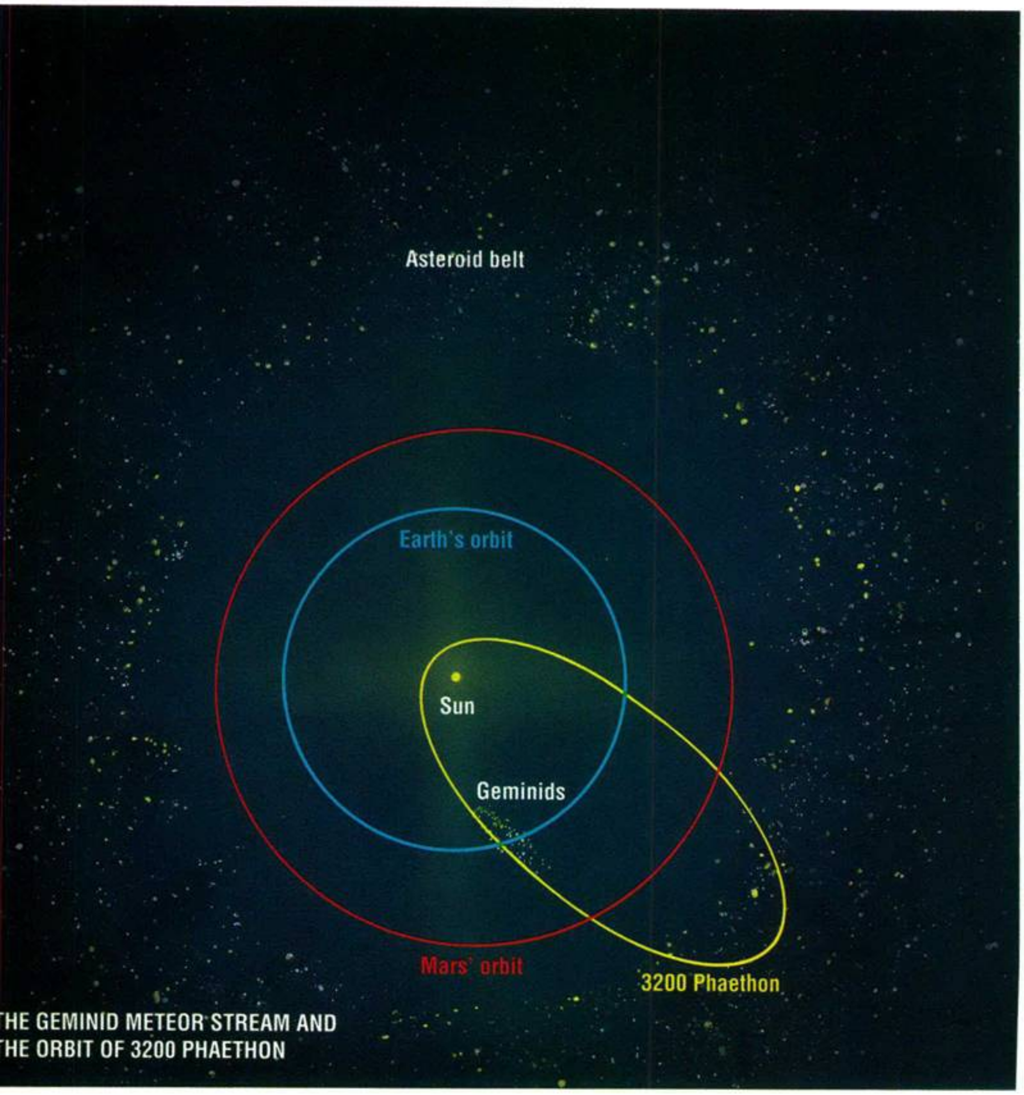
Unlike most showers that originate from particles left behind by a comet, the Geminids come from an asteroid. Discovered by the Infrared Astronomical Satellite in 1983, this asteroid now carries the name 3200 Phaethon. It was one of the first links between comets and asteroids that astronomers found. They are now debating whether Phaethon may be a burned-out comet.

Around 1960, the Geminids surpassed the Perseids as the most spectacular annual meteor shower. This year may be an exception because the parent comet of the Perseids, Swift-Tuttle, passed through the inner solar system late last year accompanied by a trail of debris. Observers saw a larger than normal number of bright Perseids last August, but you will still probably see a higher total number of Geminids than Perseids.

A New Shower

The Geminids are a relatively new meteor shower. While astronomers have watched other showers such as the Perseids for hundreds of years, Robert Greg of England and B. V. Marsh and Alex Twining of the United States discovered the Geminid shower only in 1862.

Studies of the stream over the years show its activity to be rising. The number of meteors seen per hour increased dramatically around 1900. Since then, the rates have



HE GEMINID METEOR STREAM AND
HE ORBIT OF 3200 PHAETHON

ASTRONOMY: Lee Vande Visse

GEMINIDS COME from an asteroid, 3200 Phaethon, instead of from a comet, as most other meteor streams do.

increased more slowly, reaching 60 to 110 per hour in the 1980s.

This increase is due to Jupiter's gravity, which slowly pulls the stream through Earth's orbit. Our planet first encountered the stream sometime around 1800. Astronomers believe the Geminids will come to an end by the year 2100 when the stream moves outside Earth's orbit. We're probably now passing through the densest part of the stream and enjoying the finest of the Geminid showers.

When to Observe

The Geminid stream, like most meteor streams, is rather diffuse at the edges and gets denser toward the center. As a result, you can see the shower over two weeks, but a distinct peak of activity occurs on one night. This year the peak happens on December 13 at 23 hours UT (6 p.m. EST). The Moon is New on December 13, so it sets with the Sun, providing ideal viewing conditions.

The radiant lies slightly west and north of the star Castor in the constellation Gemini (at right ascension 7h28m and declination 32°). It rises at about 6 p.m. local time and passes nearly overhead around 2 a.m. for observers at mid-northern latitudes.

The average number of Geminids when the radiant is at the zenith (called the zenithal hourly rate, or ZHR for short) is around 90. Variations in the stream's density cause this rate to fluctuate from 50 to over 100 meteors per hour. The 1988 Geminids peaked at 130 meteors per hour.

Because its radiant appears high in the evening sky, the Geminids offer good visibility before midnight. However, the best time to watch for Geminids is after local midnight when you are on the leading hemisphere of Earth as it plows through the stream of cometary debris. Before midnight, only particles moving faster than Earth can catch Earth and burn up in its atmosphere as a meteor. Playing tag with Earth makes these meteors move slowly through the sky, heating them less and causing them to be faint. Those entering after midnight move toward the speeding Earth, so they streak across the sky and appear brighter.

The average magnitude of a Geminid is 2.7, but there are many above magnitude 0. Geminids display a host of colors — blue, orange, red, and green — but most are white with some yellow. They usually last less than a second.

Observing Meteors

Observing meteors requires no special equipment, just your unaided eyes. To get the most out of the Geminids, you need a dark observing site far from major urban areas. In a city, light pollution will wash out all but the brightest meteors.

Use a flashlight with a red covering on the lens when you look at charts or record your observations. This will ensure that you don't lose your night vision.

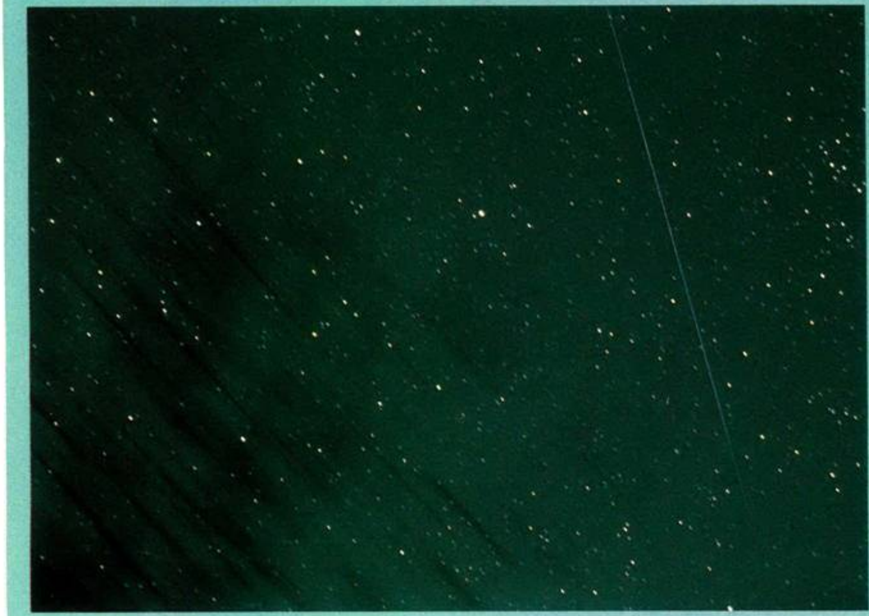
Compared to other astronomical events, meteor observing can be a social occasion. Consider watching the shower with a group of friends and make a night of it. If you can't persuade anyone to go with you, bring along some music to keep you company. Don't forget to take some munchies to eat during breaks.

Don't try to watch the entire sky at once, but rather look about 45° to 60° away from the radiant and toward a dark portion of the sky. Observing is best when the radiant is high in the sky. A low radiant means you'll miss many meteors as they shoot below your horizon.

Look for trails, glowing streaks that follow a meteor and are short-lived. About four percent of Geminids also produce trains, a faintly glowing wake of vaporized material seen after the trail dies out. Watch the train's changing appearance, caused by winds in the upper atmosphere.

If you can distinguish shower members from sporadic meteors and know how to estimate a meteor's brightness by comparing it to bright stars in the area, you may wish to record your observations and share them with a meteor society. Also record how long the meteor was visible, the time of its appearance, and any noticeable color. You

CATCH A FALLING STAR WITH YOUR CAMERA



A TRIPOD AND A CAMERA are all you need to capture the Geminids. Use a fast film (ISO 400) and 5- to 10-minute exposures.

Michael Searle

To photograph a meteor, you need only basic photographic equipment. First, you need a camera with a B (bulb) or T (time) setting. This allows you to keep the shutter open to make the long time exposures needed to capture meteors. Also you need a cable release for the B setting to lock the shutter open so you don't have to stand there and hold the shutter button down by hand.

Use a normal lens (that is, a 50mm lens for 35mm cameras and an 80mm lens for medium-format cameras). Resist the temptation to use a wide-angle lens to increase your chances of capturing a meteor passing through the camera's field. Although they cover a larger area of the sky, wide-angle and fisheye lenses generally have smaller apertures, which means they won't record fainter meteors. These lenses are good only for recording the brightest meteors, such as fireballs — meteors brighter than magnitude –4.

Set the lens to an f/stop of 2 to 2.8. Some lenses have a faster 1.4 (or even 1.2) stop that is fine for normal photography but can yield bloated star images. Stopping the lens down to f/2 or f/2.8 reduces the effects of lens aberrations, but stopping further just means light from faint meteors won't reach your film.

Film selection is also crucial to capture as many meteors as possible. High-speed films (those with ISO ratings of 200 or higher) work well. For black-and-white pictures, try T-Max 400, Tri-X 400, or Ilford HP-5. For color prints, use FujiColor 400, ScotchColor 400, or Kodak Gold 400. For color slides, ScotchChrome 400 or 1000, Ektachrome 400, and Fujichrome 400 are good choices. If you have a second camera, load it with an ultrafast film such as Fujichrome 1600D or Ektachrome P800/1600 to capture meteor trains. Use short exposures to record the wispy trains before winds disperse them.

Most meteor photographers use two techniques: fixed tripod and piggyback. The easier of the two is the fixed-tripod method, which entails attaching your camera to a photographic tripod. A heavy-duty tripod is preferable to keep the camera steady during the long exposure. Point the camera about 40° to 60° above the horizon and about the same angle away from the radiant.

Open the shutter for 5 to 20 minutes, depending on the film type, sky brightness, and meteor activity. If you see a meteor flash through the field, close the shutter. With this type of photography, the stars will trail across the frame while the meteors will appear as streaks, generally at some angle to the stars. Record pertinent camera information for each exposure, like lens, f/stop, film, starting and ending times, and sky region photographed.

The other method for photographing meteors is piggyback photography, a method whereby you mount a camera on a clock-driven telescope that tracks the stars as they move across the sky. This method yields round star images, which produce recognizable constellation patterns, as opposed to the streaks produced with fixed-tripod photography.

With either technique, a 50mm f/2 lens should allow you to record a meteor as faint as 1st magnitude if it moves across the sky quickly and 2nd magnitude if it moves slowly.

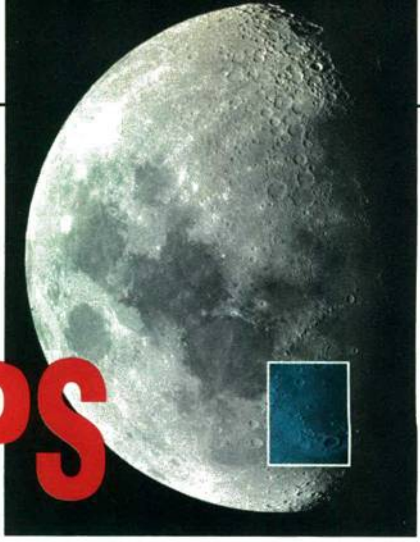
can send your report to the American Meteor Society (Department of Physics and Astronomy, State University of New York, Geneseo, NY 14454), the International Meteor Organization (181 Sifton Avenue, Fort McMurray, Alberta T9H 4V7, Canada), or the Meteor Section of the Association of Lunar and Planetary Observers (P.O. Box 16131, San Francisco, CA 94166).

If you have never observed a meteor shower before, the Geminids are a great one to start with. You can sit back and watch the celestial fireworks display or record data to further our understanding of this transient meteor shower. Regardless of your experience, the Geminids will provide plenty of thrills. ☐

Mark J. Coco is an avid astronomer living in the Los Angeles area. A frequent contributor to ASTRONOMY*, his last article was "Dialing for Deep-sky Objects" (February 1993).*

MOON OBSERVER'S NOTEBOOK

SUNRISE OVER THE LUNAR ALPS



Andrew Steinbrecher

Take a hike along the coastal mountains of Mare Imbrium.

by Michael T. Kitt

If you'd like to try a little lunar mountaineering, a good place to start is the Lunar Alps. Located in the northwest quadrant of the Moon, **Montes Alpes** (as they are formally called) trace a pathway to one of the best concentrations of outstanding features on the Moon.

The easternmost portion of the Alps comes into view just at First Quarter Moon, seven days after New. The Alps border the northern shore of **Mare Imbrium**, the huge right eye of the Man in the Moon. The Alps, the **Apennines** to the southeast, and the **Carpathian Mountains** in the south form a broken but clearly distinct circle bordering the Imbrium basin, created by a gigantic impact 3.85 billion years ago.

Recent studies suggest that after it formed, the Imbrium basin looked like a three-ring bull's eye. The Alps, Apennines, and Carpathian mountains are actually the middle ring of the original three. The innermost ring has been inundated by the lavas that oozed across the Moon during the hundreds of millions of years of volcanic activity that followed the basin-making impact. Only a few bits and pieces of this inner ring still remain, such as the isolated peaks **Mt. Pico** and **Mt. Piton.** The outermost ring of the Imbrium basin is defined by Mare Frigoris to the north.

If you observe the Moon at precisely First Quarter, you may catch sight of the **Alpine Valley** as a dark streak cutting through the hills of the eastern end of the Alps. As the Sun rises higher it illuminates the edges and floor of the valley. If you explore this area under high power you might see that the valley originates in an ill-defined bulbous area high in the southern portion of the Alps, not far from Mare Imbrium. The valley then runs downhill and ends at the southern shore of Mare Frigoris. A thin, sinuous rille snakes down the middle of the valley, but this feature is visible only through large instruments and then only under excellent seeing conditions.

The Alpine Valley is a graben, a swath of terrain dropped between two roughly parallel faults. Lava flows repaved its surface, giving it the smooth appearance it now has. The rille on this smooth floor is the remains of the lava tube that collapsed when the last of the flows ceased.

Moving west along the Alps, we come to the flooded crater **Plato**, some 100 kilometers in diameter. At low power, the dark floor looks as smooth as chocolate pudding. However, under excellent seeing conditions at high power you might spot three or four tiny craterlets.

A fascinating spectacle is the steady march of the jagged shadow cast by the eastern wall across Plato's smooth floor. This is best seen on an eight-day-old Moon. You'll be surprised at how rapidly the shadow moves as the Sun rises. Even 15 minutes are enough to change the location and shape of the shadow noticeably.

Just to the southwest of Plato, on the surface of Mare Imbrium, are two mountain formations poking through the lavas of the mare. Closest to Plato are the **Teneriffe Mountains**, and a little farther west (and off the picture at right) is the unusual **Straight Range.** As its name implies, the latter is a chain of mountains running some 80 km in a straight line. Despite their rugged appearance, these mountains are only 1,800 to 2,500 meters high. Both formations are believed to be remnants of Mare Imbrium's innermost basin wall.

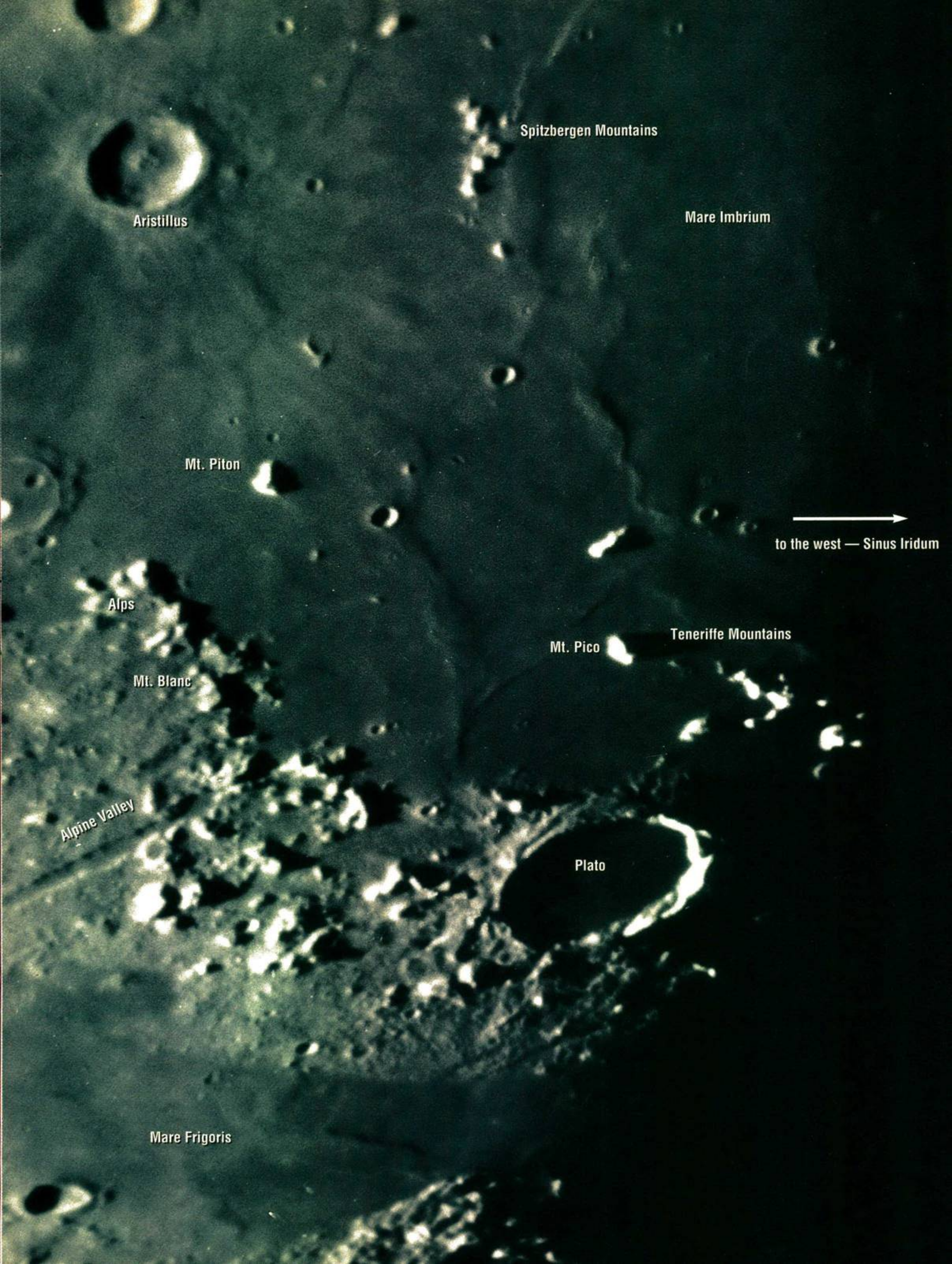
ON AN EIGHT-DAY-OLD MOON, shadows creep across the floor of Plato, one of the scenic attractions around the Lunar Alps. South is at top to match the view in an inverting telescope.

On the tenth night after New Moon, you can see the third of our morning vistas in the Alps. There is little to compare with the beauty of sunrise over **Sinus Iridum,** the Bay of Rainbows. At sunrise, this formation appears as a jewel-encrusted handle of a sword projecting out into the velvet blackness. Each of the sparkling jewels is one of the numerous tips of the **Jura Mountains**, which encircle Sinus Iridum to the west and north. The mouth of the bay is formed by two capes: The northeast point of the bay is named **Promontorium Laplace**, while the southwest point is **Promontorium Heraclides.**

Sinus Iridum is the remains of a large impact crater that formed on the surface of the Imbrium basin before the lava floods came. When they emerged to fill the Imbrium basin, the lava flows engulfed the crater, broke down its seaward wall, and flooded its interior. Stretching across Sinus Iridum from cape to cape is a prominent wrinkle ridge, strikingly visible in the grazing light of sunrise. You can see at least six more wrinkle ridges within the bay running parallel to the first, like a line of ocean waves heading toward a shore. No wonder early observers thought the Moon was covered with water. However, as you gaze at this remarkable sight, it will soon become obvious these waves never move. ☐

Michael T. Kitt is author of The Moon: An Observing Guide for Backyard Telescopes *(Kalmbach Publishing Co., 1992).*

Jean Dragesco


Spitzbergen Mountains
Aristillus
Mare Imbrium
Mt. Piton
to the west — Sinus Iridum
Alps
Teneriffe Mountains
Mt. Pico
Mt. Blanc
Alpine Valley
Plato
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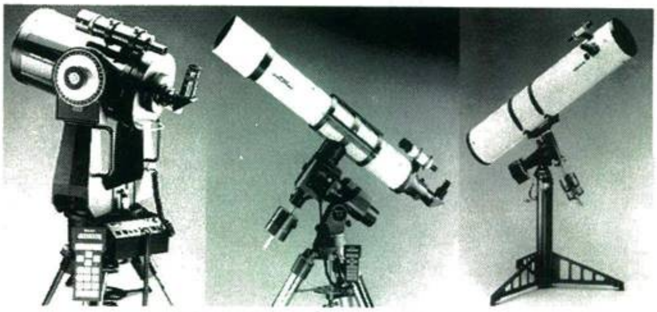

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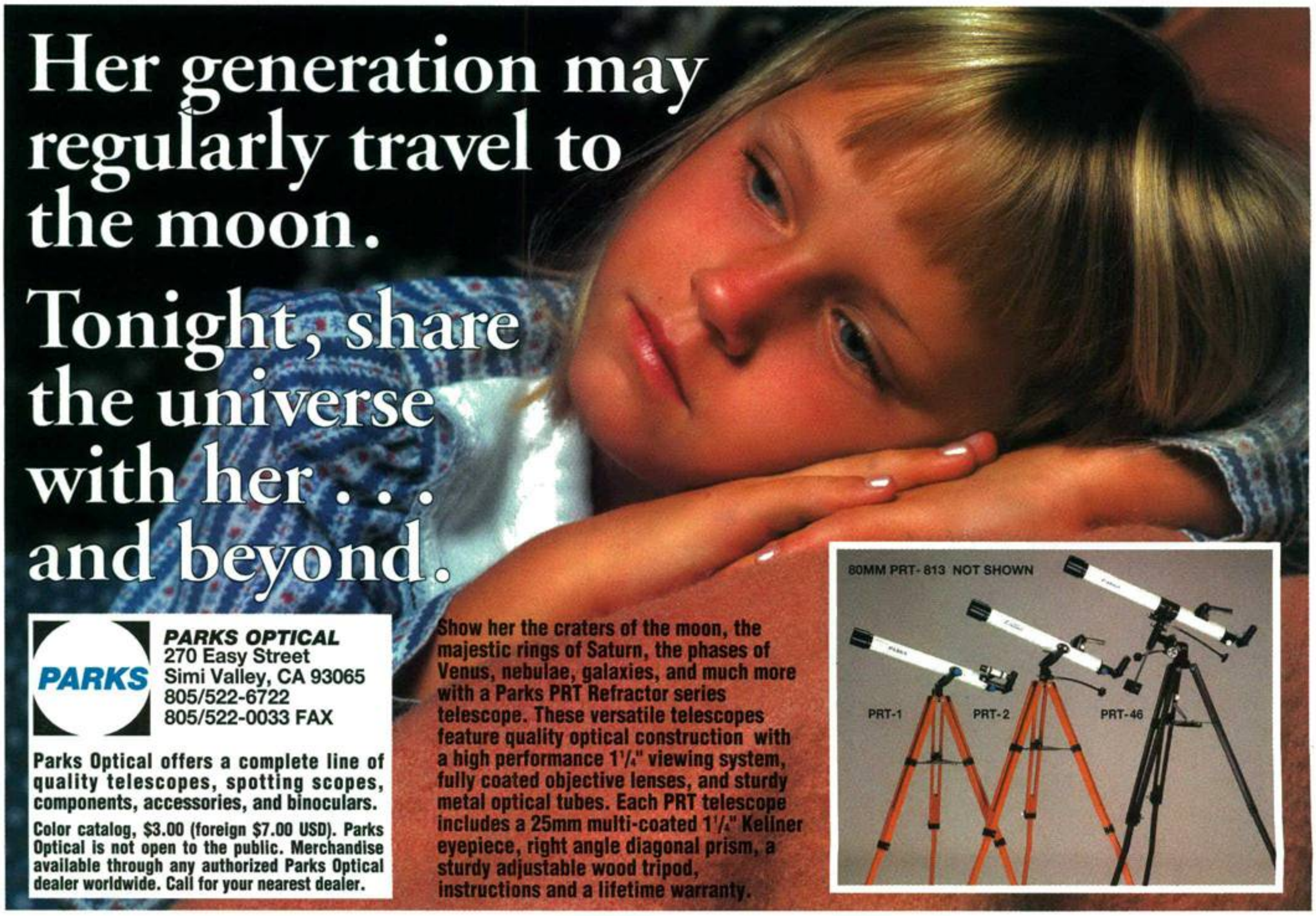
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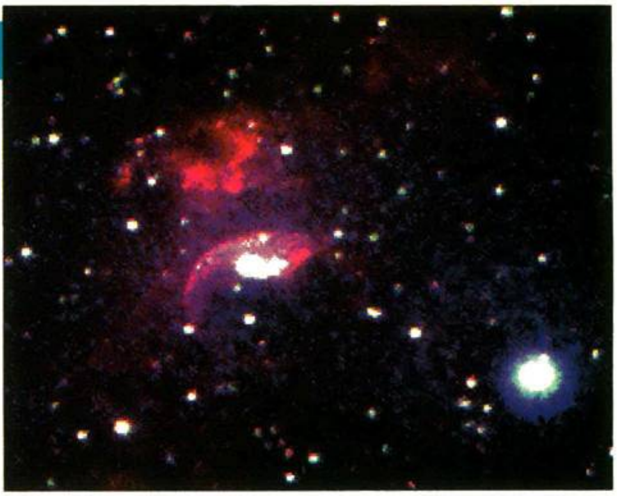


CAPTURING COLORS WITH A CCD

Who says you can't do serious deep-sky work from cloudy Britain? British astro-imagers Ian King and Nik Szymanek enjoy capturing on their computers the subtle reds of emission nebulae and blues and yellows of galaxies. Based in West Horndon, Essex, King and Szymanek use a 10-inch f/6 SCT, an SBIG ST-4 autoguider, and an SBIG ST-6 CCD camera. They spent much of August 1993 recording images of many bright deep-sky objects, including the Ring Nebula (M57), the Bubble Nebula (NGC 7635), the Veil Nebula (NGC 6960 and NGC 6992-5), the Hercules Cluster (M13), and NGC 891.

King and Szymanek's images show striking color because they take three filtered monochromatic images and combine them electronically. They use a software package called Enhance, by Owl Technology, to register, combine, and alter the color of the images. They are demonstrating that with CCD imaging, backyard observers don't need sky conditions like those at Mauna Kea to produce impressive results.

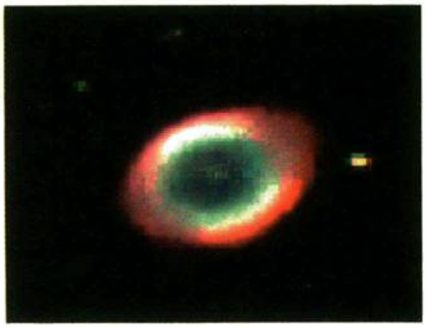
More on the Perseids. We have received large numbers of Perseid meteor reports. Although a predicted Perseid "storm" on August 12 did not materialize, observers across the United States and abroad recorded high numbers of fireballs. (See "The Storm That Got Away," page 68.)

"I just happened to move my head as I saw a great flash," says Paul Dickson of Phoenix. "Others saw shadows cast on the ground, but I simply spotted the flash from the last part of the meteor." Dickson was talking about one of several fireballs he and fellow East Valley Astronomy Club members observed. "During the hour beginning at 11 p.m. on the 11th," says Dickson, "we counted 118 meteors." Another Arizonan, Barbara A. Hartman of Cave Creek, watched as 70 meteors zipped overhead during the night. "I saw a particularly good one of about magnitude –1 that appeared greenish-blue and traveled from Cassiopeia to Aquarius," she says.

In the neighboring state of California George J. Zay of La Mesa tabulated the meteors he observed. "There definitely was no storm or exceptional shower," states Zay, "but the maximum seemed to be a little more active this year than the previous few years." Zay observed on 17 nights from July 16 to August 15, spotting the greatest activity on August 11/12 — 340 meteors, with the brightest shining at magnitude –6. He calculated the average magnitude that night as 1.3.

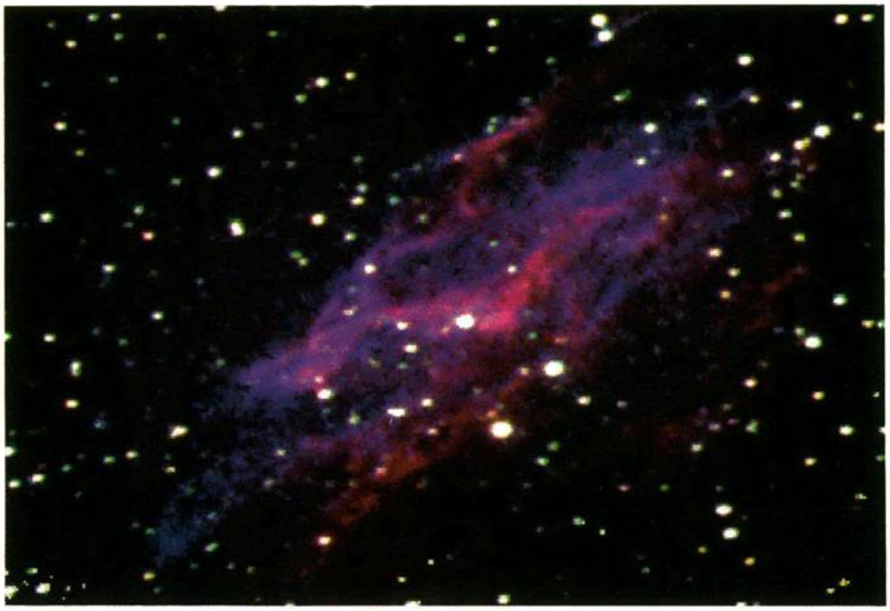
Although some were hampered by occasional clouds, most observers on the East Coast viewed the shower successfully. "Between 9:30 and 10:30 p.m. my wife and I saw 41 Perseids," says John C. Sellechio of Warwick, Rhode Island. Herman Vener of the Westport Astronomical Society in Connecticut reports a Perseid witnessed by Steven and Miriam Giskin traversed the entire sky, from Alpha Pegasi to Scorpius.

Frank J. Melillo of Holtsville, New York, was clouded out until 11 p.m., when the clouds broke up. "I saw an average of one meteor every five minutes although the horizon was permeated by haze," says Melillo. George W. Gliba of Greenbelt, Maryland, observed the shower from the Stellafane convention in Springfield, Vermont. He spotted 48 Perseids in a four-hour period. □



Astronomy wants to hear about your observations of the sky. Please send reports, sketches, and photographs to David J. Eicher, Reader Reports Editor, Astronomy, P.O. Box 1612, Waukesha, WI 53187.

COLOR CCD IMAGES made by British amateurs Ian King and Nik Szymanek show fine details in the Bubble Nebula (top), the Ring Nebula (center), and the Veil Nebula (below).



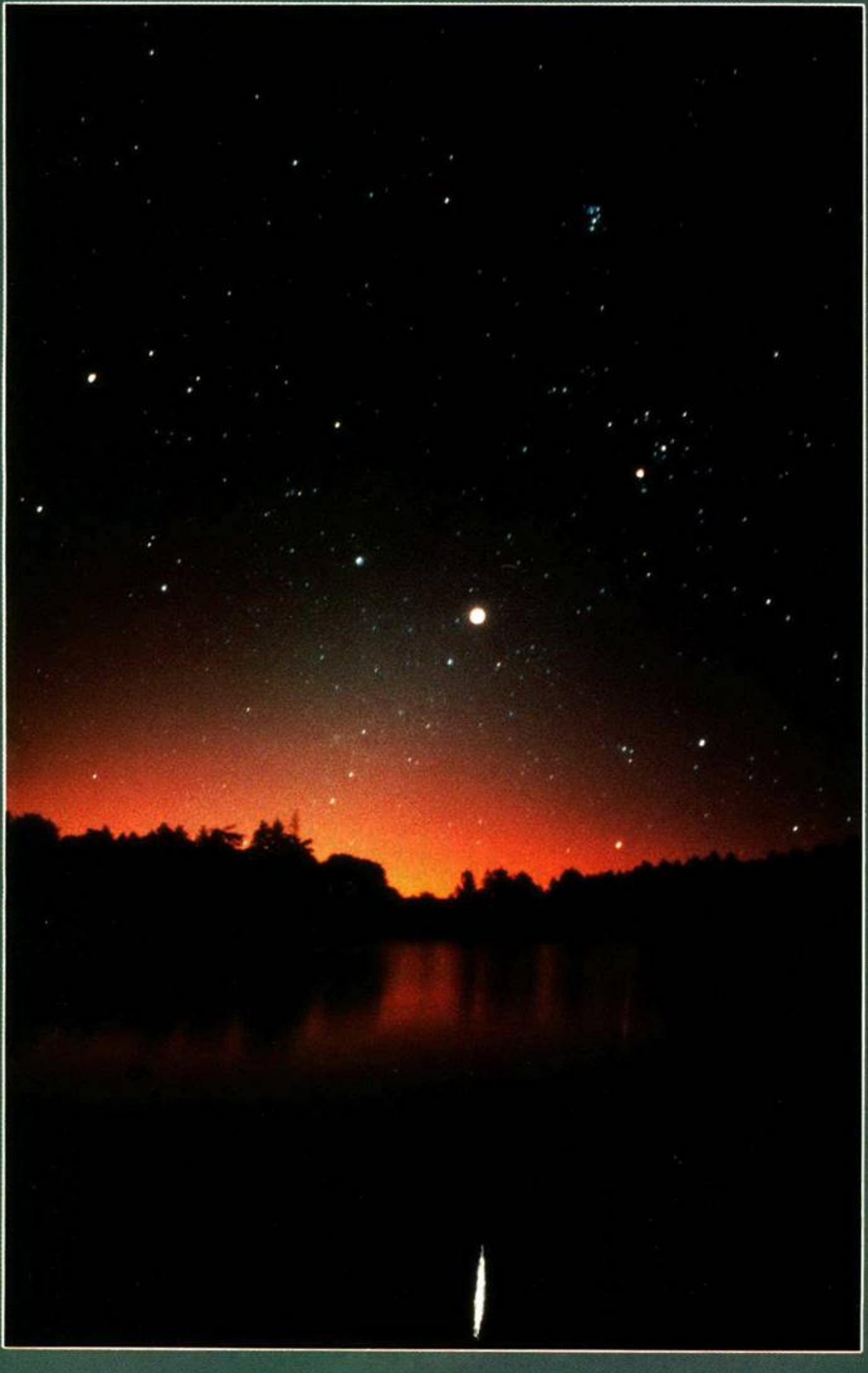
THE ALLURE OF THE MORNING SKY

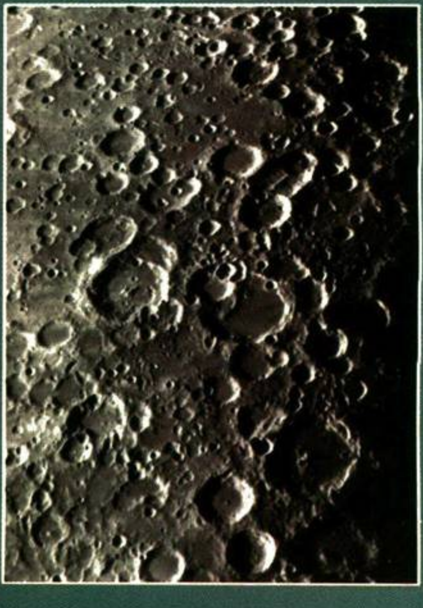
On May 18, 1993, the West Texas sky was clear. Dawn gently spilled light over the morning horizon at McDonald Observatory, illuminating its 107-inch dome with a warm glow. Michael Terenzoni of Tucson captured the Moon and Venus over the dome (right), which won him this month's $100 "Best Astrophoto" award.

French astrophotographer Jean Dragesco captured a much closer portrait of the Moon (below right). It shows us the larger craters Walter (lower right) and Stöfler (center).

Merging planets with the rich backdrop of the Winter Milky Way, Jerry Schad captured Venus as it hovered in the morning sky last July (below). Visible among the constellations are Auriga and the Pleiades and Hyades clusters in Taurus.

The California astrophotography team of James R. Foster, Michael A. Stecker, and William Fletcher captured the orange glow of galaxy NGC 5907 in Draco (opposite page, bottom). They used two 60-minute exposures shot with a 14-inch SCT on Fuji HG 400 film and combined the frames in Aldus PhotoStyler.





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OBSERVING GALAXIES

Galaxies and the Universe, edited by David J. Eicher, (Kalmbach Books, 1992), ISBN 0-913135-14-3, 112 pages, softcover, $14.95.

Galaxies and the Universe is a compilation of articles from *Deep Sky* magazine. Some of the articles describe difficult celestial targets: remote galaxy clusters, obscure planetary nebulae, and faint star clusters. Others offer far more detail about better-known sky wonders than you can find anywhere else.

Even though I have a complete collection of the magazine, which was published from 1977 to 1991, I appreciate having these 14 articles in one place. They represent the best of the magazine's offerings and include "Observing the Local Group of Galaxies" by Tom Polakis, "All about M31" by Brian Skiff, and "A Night of Galaxies near M13" by Robert Bunge. The authors are all experienced deep-sky observers with much useful knowledge to impart.

All the articles focus on observing, and both veteran and novice observers will find plenty to interest them. Each appears exactly as it did when first published and includes all the original photos, drawings, and finder charts. The earliest dates back to 1984 but most appeared in *Deep Sky* since 1989. In all cases the passage of time hasn't affected the content. This is observing material that will be useful into the next century. Editor Eicher also added a 16-page section of color photographs by some of today's best amateur astrophotographers.

This book is far from being a comprehensive guide to galaxies, but this was clearly never the intention. *Galaxies and the Universe* will augment your deep-sky observing library, not form its core. And for those who were not able to enjoy the pages of *Deep Sky* magazine before it expired of natural causes in 1991, this is an especially welcome volume. — *Terence Dickinson*

Cosmology
The Light at the Edge of the Universe, by Michael D. Lemonick, (Villard Books, 1993), ISBN 0-679-41304-9, 325 pages, acid-free paper, hardcover, $24.

Subtitled *Leading Cosmologists on the Brink of a Scientific Revolution,* this book describes the current debate regarding the ability of big bang models to describe the origin of the universe. Lemonick, an associate editor at *Time* magazine, describes astronomers' struggles with measuring the size and age of the universe, explaining how galaxies came to be, and predicting the future of the universe. He tells about the science of cosmology as seen through the eyes of the participants and takes us into the observatories and scientific meeting rooms where astronomers are trying to resolve the present crisis in cosmology.

Children's Book
Stars and Planets, by Ian Ridpath, (Facts on File, 1993), ISBN 0-8160-2926-1, 80 pages, hardcover, $16.95.

Young readers will find lots of photos and illustrations accompanying the descriptions of telescopes, planets, the Sun, stars, constellations, our Galaxy, and the universe. The book is up to date, including Magellan radar images of the surface of Venus and a picture of the 10-meter Keck telescope in Hawaii.

However, the only star map is an equatorial map showing the stars plotted by right ascension and declination. Seasonal star maps would have been a better choice for young astronomers. So if you purchase this book for a young friend or relative, you might want to also buy a planisphere to go with it.

Astronomical Projects
Exploring the Sky, by Richard Moeschl, (Chicago Review Press, 1993), ISBN 1-55652-160-X, 413 pages, softcover, $14.95.

Moeschl has revised this popular book of projects for beginning astronomers and middle school and older students. The 72 projects cover everything from using a Mayan calendar to making a simple telescope. Explanatory material accompanies the projects to help the reader understand the context of each experiment. Moeschl deleted some of the projects in the previous edition and added some new ones.

Space Exploration
Inside NASA, by Howard E. McCurdy, (The Johns Hopkins University Press, 1993), ISBN 0-8018-4452-5, 215 pages, acid-free paper, hardcover, $32.95.

NASA has received considerable criticism lately for its inability to produce inexpensive planetary probes and for its management of the Space Station project. McCurdy traces these problems to the evolution of NASA from a purely technical organization faced with

[continued on page 94]

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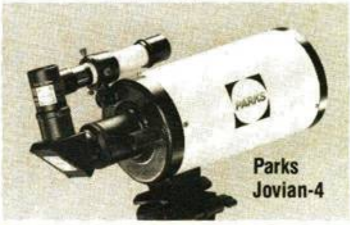

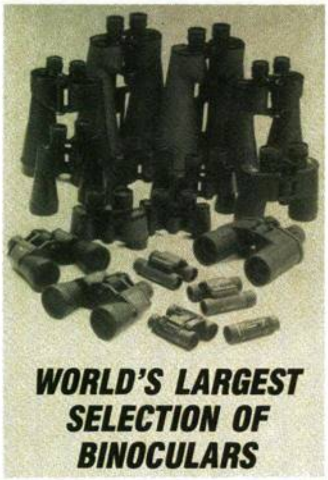

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putting a person on the Moon to a bureaucratic one. He also predicts that it will require some time to put NASA back on track.

Star Stuff

The Fullness of Space, by Gareth Wynn-Williams, (Cambridge University Press, 1992), ISBN 0-521-35591-5, hardcover, $65; softcover, $29.95.

The space between stars isn't empty. It's full of gas and dust that often accumulate in large clouds called nebulae. *The Fullness of Space* explains where this material comes from, how it glows, and how new stars form from it. Many color photos of galaxies and nebulae accompany the text, which is aimed at the general reader.

Observatory Tales

Beyond Southern Skies, by Peter Robinson, (Cambridge University Press, 1992), ISBN 0-521-41408-3, 357 pages, hardcover, $75.

This account of the Parkes radio telescope in Australia starts with the beginnings of radio astronomy in the 1920s and its detour into radar during the war years. Australia was a leader in the development of radio astronomy in the late 1940s and 1950s, and the construction of the Parkes instrument in the late 1950s was a symbol of this success. The scope remains important because of its searches for pulsars and quasars.

Advanced Topics

The Cambridge Guide to Astronomical Discovery, by William Liller, (Cambridge University Press, 1992), ISBN 0-521-41839-9, 257 pages, hardcover, $29.95.

Have you ever wondered how to search for comets, asteroids, and supernovae to make that once-in-a-lifetime discovery? Liller describes the basic techniques and equipment needed to search for new stars and solar system objects and the process for reporting your find. He also includes short essays by 20 discoverers about their methods and experiences. A bibliography lists charts and books that you'll need in a search for new objects.

Other Books Received

Interavia Space Directory, edited by Andrew Wilson, (Jane's Information Group, 1992), ISBN 0-7106-1001-7, 654 pages, softcover, $225. A thorough description of national space programs, launchers, navigation, Earth observation, world space centers, and the space industry, with many black-and-white photos and illustrations. ☐

Readings & Credits

The Star That Blew a Hole in Space (page 30)

"Discovery of Soft X-ray Pulsations from the Gamma-ray Source Geminga," by J. Halpern and S. Holt, *Nature*, volume 357, page 222. This paper reports Geminga as a pulsar.

"The Proper Motion of Geminga's Optical Counterpart," by G. Bignami, P. Caraveo, and S. Mereghetti, *Nature*, volume 361, page 704. They measure Geminga's proper motion, which helped establish the supernova's proximity to Earth.

Death from the Sky (page 38)

Giant Meteorites, by E. L. Krinov, (Pergamon Press, 1966). Includes a chapter on Tunguska that is the best story of Kulik's pioneering research.

"The 1908 Tunguska Explosion: atmospheric disruption of a stony asteroid," by Christopher F. Chyba, Paul J. Thomas, and Kevin J. Zahnle, *Nature*, volume 361, page 40. The technical details of the author's computer modeling.

"Explosions of Small Spacewatch Objects in the Earth's Atmosphere," by Christopher F. Chyba, *Nature*, volume 363, page 701. Examines the potential threat from known Spacewatch objects.

The Odd Little Moons of Mars (page 48)

Moons of the Solar System, by John Stewart, (McFarland and Company, 1991). Describes the physical characteristics, discovery, and surface features of all the known planetary satellites.

"New Views of Mars and Phobos," by Robert Burnham, ASTRONOMY, September 1989. A look at the Soviet Phobos 2 mission to the Red Planet.

The Storm That Got Away (page 68)

Meteor Showers; a descriptive catalog, by Gary W. Kronk, (Enslow Publishers, 1988). Includes basic data for the Perseid meteor shower and several dozen more, along with observing tips.

Meteors, by Neil Bone, (Sky Publishing Corp., 1993). An introductory guide to meteor observing including information on meteor photography.

Orion's Low-Cost Dobsonians (page 74)

"ASTRONOMY Tests Affordable Reflector Telescopes," by Alan Dyer, ASTRONOMY, December 1991. A comparison test of 12 Newtonian reflectors under $1,000. Some models featured in the test have now been discontinued or replaced.

Catch the Geminid Meteor Shower (page 82)

"Observe the Geminids Before They Disappear," by Philip M. Bagnall, ASTRONOMY, December 1990. A more complete description of the orbit of the Geminid stream and how it is changing.

Sunrise Over the Lunar Alps (page 86)

Atlas of the Moon, by Antonín Rükl, (Kalmbach Publishing, 1992). A superb atlas of 76 large-scale maps that portray the nearside of the Moon.

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6"	79.00	6"	69.00
8"	95.00	8"	85.00
10"	109.00	10"	99.00
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4-1/4" to 5"	96.00	4-1/4" to 5"	86.00
6"	105.00	6"	95.00
8"	125.00	8"	109.00
10"	139.00	10"	119.00
11"	149.00	11"	139.00
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3.5" to 4"	99.00	3.5 to 4"	79.00
4-1/4" to 5"	125.00	4-1/4" to 5"	110.00
6"	135.00	6"	115.00
8"	159.00	8"	139.00
10"	172.00	10"	152.00
11"	199.00	11"	179.00
12.5" to 13.1"	229.00	12.5" to 13.1"	209.00
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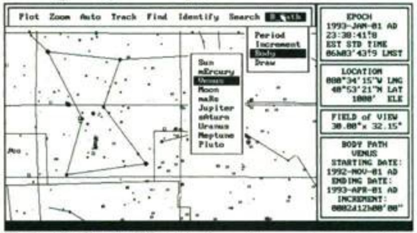

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New Astronomy Products

1 Losmandy GM-8 Mount

Hollywood General Machining has introduced a lightweight mount, the Losmandy GM-8. A smaller version of the popular G-11 mount, the GM-8 is designed to handle 8-inch Schmidt-Cassegrain tube assemblies, Newtonian reflectors up to 6-inch f/6, and refractors up to 5-inch f/8 (shown with Genesis refractor). Construction is all-machined aluminum and stainless steel. Features include manual slow-motion controls, a metal tripod with leg levelers, an optional dual-axis drive with periodic error correction, three photo guide rates, three setting rates, four tracking rates, and anti-backlash compensation. The GM-8 is available exclusively from Pocono Mountain Optics and Spectra Astro Systems.

Pocono Mountain Optics, RR 6, Box 6329, North Pocono Village Shopping Center, Moscow, PA 18444, (717) 842-1500 or *Spectra Astro Systems, 6631 Wilbur Avenue, Suite 30, Reseda, CA 91335, (818) 343-1352. Mount: $879; dove plate adapter: $49; dual-axis drives and electronics: $369; polar alignment scope: $149. Complete package (introductory price): $1,349.*

2 An Adjustable Observer's Chair

The Observer's Chair is hand-crafted from solid oak and features a seat that slides up and down the back of the chair. The motion requires no lining up of notches or adjustment of any knobs or buttons. The seat height is adjustable from 18 to 36 inches. The seat slides off the top of the chair and the base folds flat for ease of storage and transport.

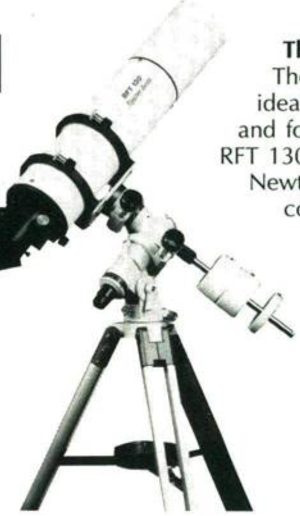
K.C. Woodsmith, P.O. Box 75033, Wichita, KS 67275-0033. $69.95 plus $10 shipping.

3 Supplies for Telescope Makers

Salem Distributing Company is offering amateur-sized lots of abrasive, pitch, polish, polishing pads, and diamond-generating tools. The five-pound packages of abrasive and polish are suitable for telescope makers. Polishing pads are available in rolls of 50 in three sizes: $2^1/2$ by 3", 3", and $3^1/2$".

Salem Distributing Company, Inc., Box 25566 Manor Station, Winston-Salem, NC 27114, (919) 659-7112, fax (919) 659-8670. Write or call for a complete list of prices.

4 The ARO Instruments RFT 130



The RFT 130 is a 5.1-inch f/5 achromatic refractor ideal for viewing comets and large deep-sky objects and for low-power sweeping of Milky Way vistas. The RFT 130 can also serve as a large-aperture finder for big Newtonian telescopes. The air-spaced objective lens is coated on all four surfaces and is promised to be diffraction limited. The 3-inch-diameter Crayford-style focuser comes with adapters for 2-inch and $1^1/4$-inch eyepieces. Weight of the 31.5-inch-long tube assembly is 11.5 pounds. The tube is aluminum and comes with a 9-inch-long dewcap and vinyl dust cover. An optional German equatorial mount (shown) is available.

ARO Instrument Company, 1245 S. 6th Street, Coshocton, OH 43812, (614) 622-8895, fax (614) 622-3231. $995.

[continued on page 100]

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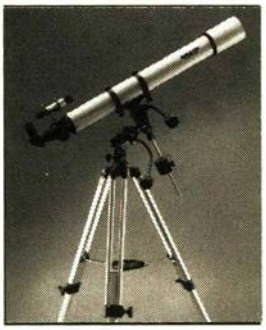

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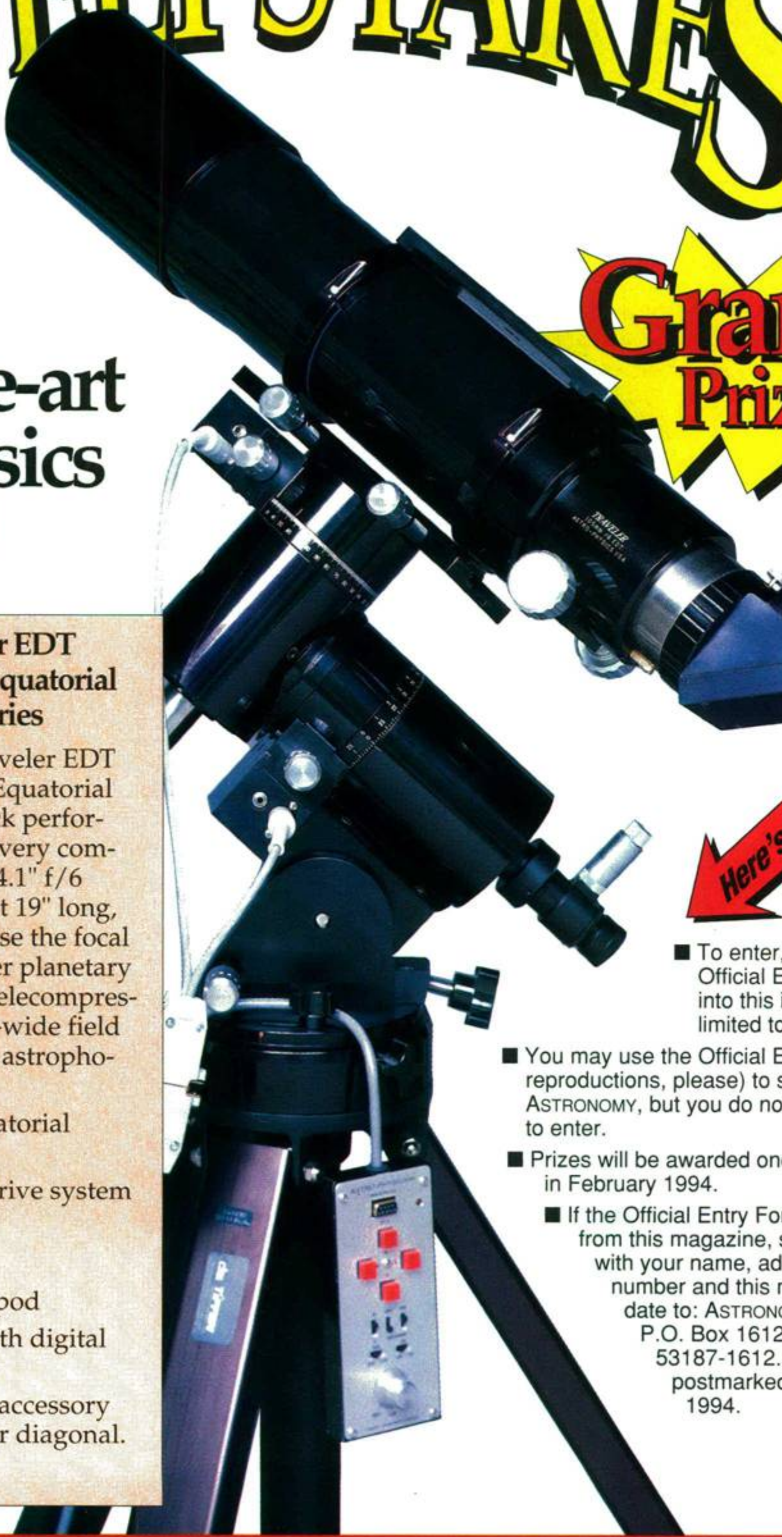

Grand Prize

Win this state-of-the-art Astro-Physics Telescope!

Astro-Physics 105 Traveler EDT and Model 400 German Equatorial Mount plus other accessories

The Astro-Physics 105 Traveler EDT and Model 400 German Equatorial Mount were designed to pack performance and versatility into a very compact package. The exquisite 4.1" f/6 apochromatic refractor is just 19" long, yet the 2x Barlow will increase the focal length to f/12 for high-power planetary viewing. And the included telecompressor will allow f/4.5 for ultra-wide field viewing and short-exposure astrophotography.

The Model 400 German Equatorial Mount package features:

- Quartz control dual-axis drive system
- Dovetail mounting plate
- Polar axis telescope
- Lightweight aluminum tripod
- Built-in encoders to use with digital setting circle computers

Additional items include an accessory mounting plate and 2" mirror diagonal.

Retail value: $4678.00

Here's how to enter!

- To enter, complete the Official Entry Form bound into this issue. Entries are limited to one per person.
- You may use the Official Entry Form (no reproductions, please) to subscribe to ASTRONOMY, but you do not have to subscribe to enter.
- Prizes will be awarded once from all entries in February 1994.
- If the Official Entry Form is missing from this magazine, send a postcard with your name, address, home phone number and this magazine's issue date to: ASTRONOMY Sweepstakes, P.O. Box 1612, Waukesha, WI 53187-1612. Cards must be postmarked by January 31, 1994.

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1st Prize

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An achromatic 6x30 straight-through finder scope and a complete set of four premium Sirius Plössl 1.25" eyepieces are included.

3 winners!

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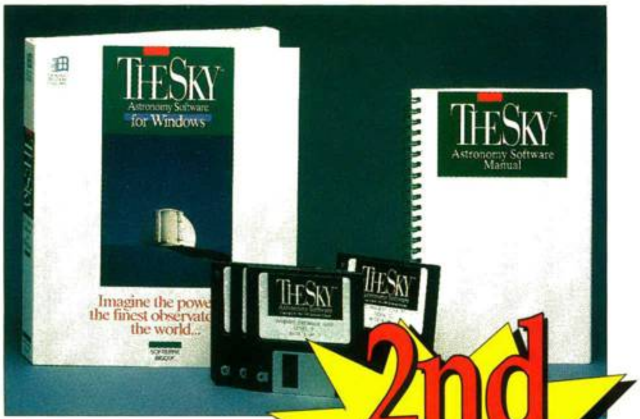

2nd Prize

TheSky and SkyPro software

Explore the heavens on your PC! If you're one of our six Second Prize winners you'll receive TheSky for Windows featuring over 55,000 deep sky objects and 75 full-color images. Plus, you'll learn about CCD astronomy with SkyPro image processing software from Software Bisque.

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3rd Prize

ASTRONOMY 3-year subscriptions.

Last, but certainly not least, 24 winners will be awarded a three-year subscription to ASTRONOMY magazine. If you are a current subscriber, the prize will begin after your subscription expires.

24 winners!

No purchase necessary. All prizes will be awarded.

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2. Entries are limited to one per person. All entries must be postmarked by January 31, 1994 to be eligible for all prizes, to be awarded in February 1994.
3. Winners will be selected in random drawings and decisions are final. Winners will be notified by mail and/or telephone. Any prizes returned as undeliverable will be awarded to alternate winners. Chances of winning are determined by the total number of entries received.
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Tom Johnston, Boulder, Colo.

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"Careful star-testing of the 10.1" Odyssey Compact I received last March and of the 10.1" my neighbor Doug Barnes picked up in mid-October suggests a high level of quality control which is astonishing. Diffraction patterns are virtually interchangeable, and both scopes show textbook optical results (both in-focus and out-of-focus)."
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Mark Davenport, Pinellas Park, Fla.

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David Broad, Santa Barbara, Ca.

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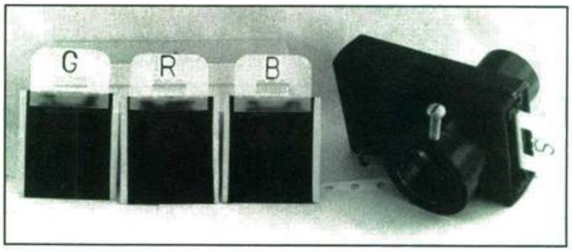
5

A Filter Kit for Tri-Color CCD Imaging

Designed to attach to $1^1/_4$-inch focusers, the CF-1 Filter Unit allows CCD imagers to take three filtered monochrome shots for assembling true-color CCD images. The CF-1 includes three color filters (#25 red, #58 green, and #47 blue, plus a dark slide) installed in a manually operated sliding mechanism. When using the provided filters, you don't need to refocus when switching them.

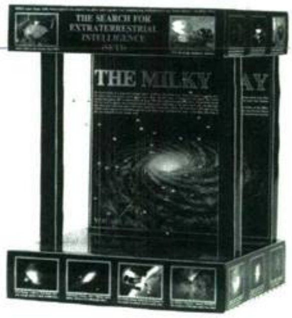


Galactic Images, 2105 Wyoming Street, Dayton, OH 45410, (513) 256-5014. Introductory price: $125 plus $5 shipping.

6

Educational Kits from Novascience

A new science kit allows you to construct a three-dimensional model showing the location of the 37 brightest stars in our sector of the Milky Way. The finished model measures $13^1/_2$" by $10^3/_4$" by $9^1/_2$" and includes a 32-page booklet. Also available, *The Grand Canyon of Mars* (not shown), a three-dimensional model of Valles Marineris mounted inside a full-color frame measuring $20^1/_4$" by $13^1/_2$" by $^3/_4$". Each kit comes in an attractive gift box and is available in many museum gift shops and nature stores or directly from the manufacturer.



Novascience, Inc., 1220 E. Greg Street #14, Sparks, NV 89431, (702) 331-4994. Each kit: $24.95 plus $5 shipping and handling.

7

A Home Weather Station

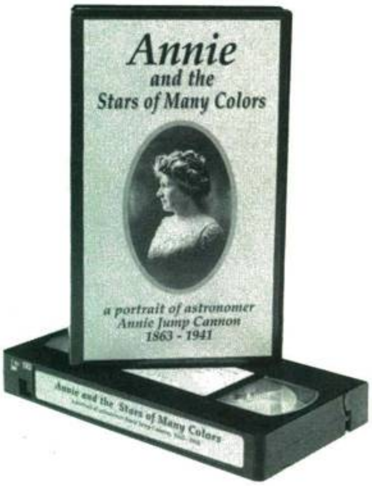
The WS-12 WindStation allows users to measure and log wind speed, wind direction and temperature on a personal computer. The WindStation connects to the parallel (printer) port of any MS-DOS computer.

WeatherPort, P.O. Box 240, Grass Valley, CA 95945-0240, (916) 477-5226, fax (916) 477-8339. $295.

8

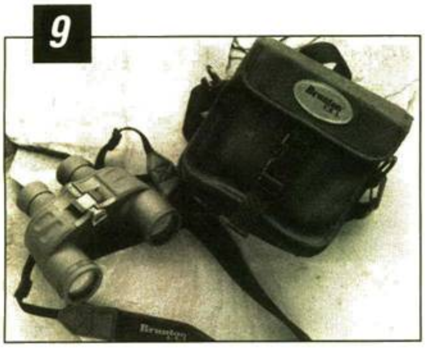
New Biographical Video

The Harvard-Smithsonian Center for Astrophysics has released a 25-minute video called *Annie and the Stars of Many Colors: A Portrait of Astronomer Annie Jump Cannon*. The video explores the life and work of the astronomer who classified the spectra of nearly 400,000 stars. The video is aimed at young people but provides an inspiring biography of a remarkable astronomer that can certainly be enjoyed by all.



Annie Cannon Video, Publications Dept., MS 28, Harvard-Smithsonian Center for Astrophysics, 60 Garden Street, Cambridge, MA 02138. $39.95 (includes shipping and handling).

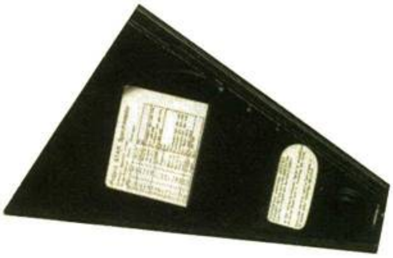
9



New Brunton Binoculars

Brunton has expanded its Eterna line of binoculars by adding an 8x40 model (shown) to the 7x42 and 10x50 binoculars already available. All are porroprism binoculars and feature long eye relief (21 to 22mm) for eyeglass wearers, waterproof nitrogen-filled construction, and Brunton's Starfire multi-coatings.

The Brunton Company, 620 East Monroe, Riverton, WY 82501, (307) 856-6559, fax (307) 856-1840. 7x42: $349; 8x40: $359; 10x50: $369.



10 **Educational Spectroscope**

The Precision Spectrometer developed by Project STAR at the Harvard-Smithsonian Center for Astrophysics is designed for educators wishing to demonstrate spectra. The spectrometer uses a holographic diffraction grating to produce a high-resolution spectrum. The scale in the viewer is labeled with both wavelength (in nanometers) and photon energy (in electron volts).

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CHAPTER 12

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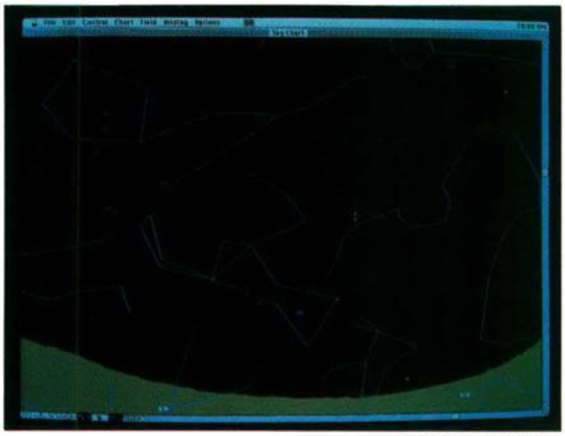

ASTRONOMY: Darla Evans

***Voyager II**, Carina Software, 830 Williams Street, San Leandro, CA 94577, (510) 352-7328. Price: $159.95. Minimum requirements: Macintosh Plus, 1 MB of memory (2 MB for large monitors), hard disk with 1.5 MB of free space, System 6.0.5 or 7.X. Optional variable-star, double-star, and deep-sky object catalogs are available for $25 each and the SAO star catalog extension to 10th magnitude is $45.*

Voyager II is an excellent planetarium-type program. It shows the positions of stars down to 8th magnitude and 4,200 deep-sky objects as faint as 14th magnitude. You can find the positions of the planets for any night, plot the path of next year's annular solar eclipse, and print a finder chart for use at your telescope.

Your viewpoint isn't limited to Earth. You can plot the sky as it appears from any of the planets. For example, you can watch from the Moon as the Moon's shadow sweeps across Earth during a solar eclipse. The solar neighborhood display lets you explore the space occupied by the 300 stars nearest to the Sun.

Several different functions help you find stars, asterisms, constellations, planets, comets, asteroids, and deep-sky objects. Some of these are quick-find menus while others allow you to search the database more thoroughly. Once the object is found, you can center the object in the display with a click of the mouse. Clicking on an object in a sky map brings up a window that identifies the object and gives its other designations, right ascension, declination, altitude, azimuth, brightness, distance, and rise and set times. A button permits you to label the object and another button will display images (30 are supplied with Voyager) associated with the object. You can also add images of your own (in the PICT format) to the image files.

You can select one of four coordinate systems — galactic, altazimuth, ecliptic (measured from Earth's orbit), and equatorial (right ascension and declination) — and superpose the grid on your sky map. You can also add the outline of the Milky Way and reference points such as the zenith and celestial poles. The stellar database includes 600 variables and 1,200 binary stars. You can plot constellation lines, figures, and boundaries as well as label stars, constellations, and deep-sky objects. Choosing from a list of roughly 500 objects, you can display 24 comets and asteroids at a time. You can add new objects to the databases and use any data files you created with Voyager 1.2.

The accuracy of the program is good and it includes precession for plotting past and future stellar positions. Pluto's position, a good test of a program's ability to calculate planetary orbits, was within a few arcminutes of the *Astronomical Almanac* value.

Voyager makes customizing star charts easy. You can adjust stellar and deep-sky object magnitude limits and change the sizes of the dots used to represent stellar brightness. You can also custom design the horizon to represent the hills and buildings around your observing site. If you want to add special objects to the database, you can design a distinctive symbol for the objects. And you can save the map as a PICT file and then use it in a report or observing log.

A feature called the "Planet Report" provides detailed information about opposition dates, lunar phases, Jupiter's moons, and planetary positions and distances. Voyager also has a conjunction search feature that doubles as an eclipse finder.

The program doesn't run a telescope but Carina Software has announced the release of SkyPilot, which will control Meade LX200 and LXD mounts. Owners of Voyager will be able to upgrade to Voyager SkyPilot, and Voyager SkyPilot will include a copy of Voyager II for new users. Contact Carina Software for more information.

Overall, Voyager II is a powerful program that will provide for almost all of your astronomical computing needs. Voyager 1.2 users will find many new features — color graphics, images, the planet report, a new control panel, and comet and asteroid orbits to name a few — that add to Voyager's versatility. You'll enjoy spending many hours with this program as you explore its many splendid and easy-to-use features. — *Dave Bruning*

NEW SOFTWARE

WinTrak*, 111 Emerald Drive, Harvest, AL 35749-9213, (205) 837-0084. Price: $49.95 plus $4 for shipping. Minimum requirements: 80286-based computer operating at 20 MHz, 2MB of memory, 3.5" disk drive, a hard disk with 3 MB of free space, and Windows 3.X. Recommended: math coprocessor.*

This Windows-based program tracks multiple satellites from a database of over 600 satellite orbits. You can display the satellites' paths across Earth or through the sky against background stars as seen from one of 850 cities. You can add orbital elements to the database using standard two-line element sets from NASA or NORAD.

REDSCOPE (version 3.84)*, Waldee-Wood Astronomical Software, distributed by Allegro Music, 1468 Kimberly Drive, San Jose, CA 95118, (408) 723-3655. Price: $49.95; upgrade for registered users is $12.95. Minimum requirements: IBM PC-compatible computer, DOS 2.0, and 320 KB of memory.*

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dark adaptation when you use the program at your telescope. This new version has context-sensitive help, saves scope-eyepiece configurations, adds 21 eyepieces to the database, supports 1.25" coma correctors, and has enhanced printer control and new help files.

***PhotoStyler (version 2.0)**, Aldus Corporation, 411 First Avenue South, Seattle, WA 98104-2871, (206) 628-2320. Price: $795; upgrade from 1.1 is $150. Minimum requirements: 80386-based computer, 6 MB of memory, hard drive, VGA display, Windows 3.X, and a mouse.*

PhotoStyler is a Windows-based digital imaging program that lets you edit, filter, and display color and black-and-white images. It uses Kodak's Precision Color Management system to achieve accurate and consistent color from display monitors and output devices. This means you can obtain the best possible color from input devices such as a Kodak Photo CD and display it properly on a monitor or output it on a color printer. A proof mode lets you see how the image will appear when printed on a selected output device.

A multi-preview mode lets you try many different filters or brightness-and-contrast enhancements before choosing a final setting. A similar dialog box lets you preview resizing and other image transformations before applying the process to the image itself. You can process part of a large image, store the partial result in the original image file, and then access another part of the image for editing or enhancement. PhotoStyler supports the following image file formats: TIFF, DCS, JPEG, and PICT. Its features tie closely to those in PageMaker 5.0, making it easy to size an image for a document.

Watch Comet Shoemaker-Levy 9 Hit Jupiter

Dance of the Planets (version 2.5s) has an improved ephemeris with the precision needed to plot next July's impact of Comet Shoemaker-Levy 9 on Jupiter's far side. It's the only commercial software presently available that will let you simulate this impact. The new version of Dance also permits you to print star charts. The tutorials, which were already pretty good, are even better now. Contact ARC Science Simulations, P.O. Box 1955A, Loveland, CO 80539, (800) 759-1642 for more information. Dance costs $195 and requires an 80286-based computer, VGA graphics, and a hard disk. ☐

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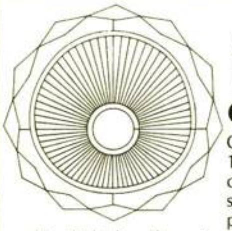

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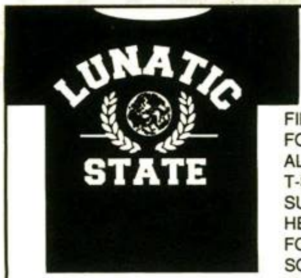

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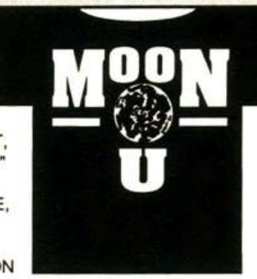

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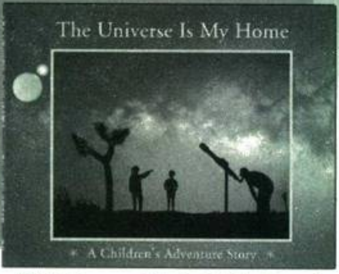

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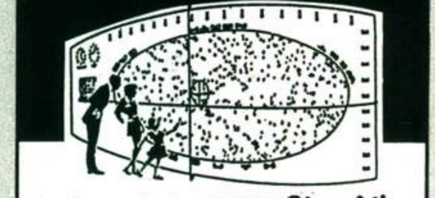

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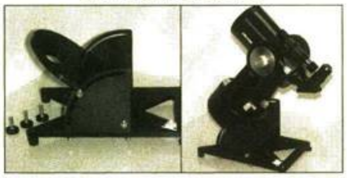

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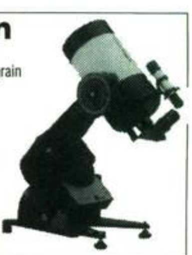

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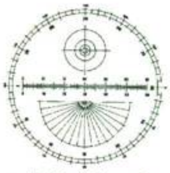

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2nd Annual Star Party, Lake Kissimmee State Park (15 miles east of Lake Wales), Florida. Contact George Aycrigg, 14248 Camp Makch Road, Lake Wales, FL 33853, (813) 696-1812 evenings.

November 19-20
Fall Spectacular, Lemon Lake County Park, Crown Point, Indiana. Featuring "The Moon and Saturn." Sponsored by the Calumet Astronomical Society. Contact Stephen J. Miller, (219) 845-9174.

December 11
3rd Annual ASV Star-Be-Cue, near Melbourne, Australia. Sponsored by the Astronomical Society of Victoria. Contact Perry Vlahos, 103a Orrong Crescent, North Caulfield, Victoria, 3161 Australia, phone (03) 527-8719.

January 11-15
183rd Meeting of the American Astronomical Society, Washington, D.C. Contact AAS Executive Office, 1630 Connecticut Avenue, NW Suite 200, Washington, D.C. 20009, (202) 328-2010.

February 7-13
Winter Star Party, Key West, Florida. Sponsored by the Southern Cross Astronomical Society, Inc. Contact Bob or Sharon Grant, 5401 SW 110 Avenue, Miami, FL 33165, (305) 595-8778.

March 14-18
25th Lunar and Planetary Science Conference, NASA Johnson Space Center, Houston, Texas. Sponsored by the Lunar and Planetary Institute and the NASA Johnson Space Center. Contact LeBecca Simmons, Conference Administrator, LPI Publications and Program Services Department, 3600 Bay Area Boulevard, Houston, TX 77058, (713) 486-2158.

April 30
48th Annual Convention of the North Central Region of the Astronomical League, John H. Witte Observatory, Burlington, Iowa. Sponsored by the Southeastern Iowa Astronomy Club. Contact Dave or Marion Bachtell, 1901 South 10th Street, Burlington, IA 52601, (319) 753-1442. ☐

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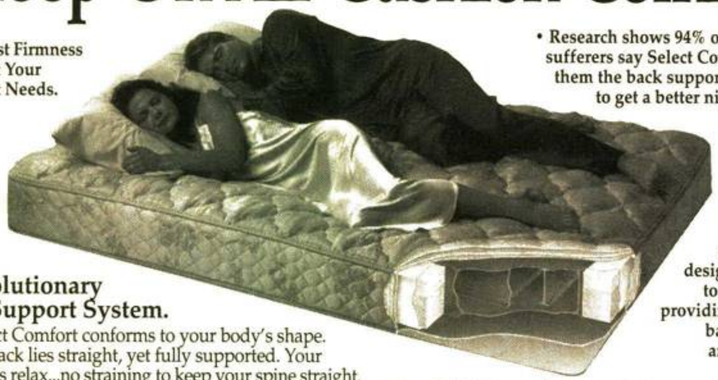

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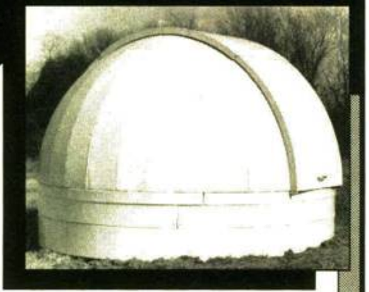

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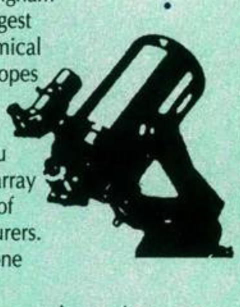

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Al Nagler designed Pronto for beginners who want an easy to use, quality instrument as well as for the advanced enthusiast who always want a diffraction limited scope handy. This versatile little performer has a power range from 9x to 250x with a maximum true field of 5.5°. Like the Genesis-sdf, we take tremendous pride in building each Pronto. Following are just a few of the wonderful unsolicited comments we've received from Pronto owners' warranty cards.

- Requirements: simple enough to learn on and teach my kids; good enough so that I won't keep wondering if I should have bought something "better;" super portable. No picture or description prepared me for the beauty of the design or the excellence of the workmanship. J.T. - RI

- It is of the usual Tele Vue perfection. S.B. - PA

- I have a 10" Newtonian and wanted a little scope for quick looks at the sky and daytime nature study. What a beautiful, perfect little instrument! The detail it shows on Jupiter is absolutely unbelievable. B.D. - CO

- Love at first sight. I never thought another scope would give me as much enjoyment as my Genesis. I was wrong. J.K. - IN

- I was able to see Jovian lunar shadow transit easily with this instrument. I love the design and features - I may have to buy a Genesis! R.G. - PA

- It's almost as if I'm not using a scope at all. Too many scopes just get in the way and make observing a frustrating experience. T.Z. - NY

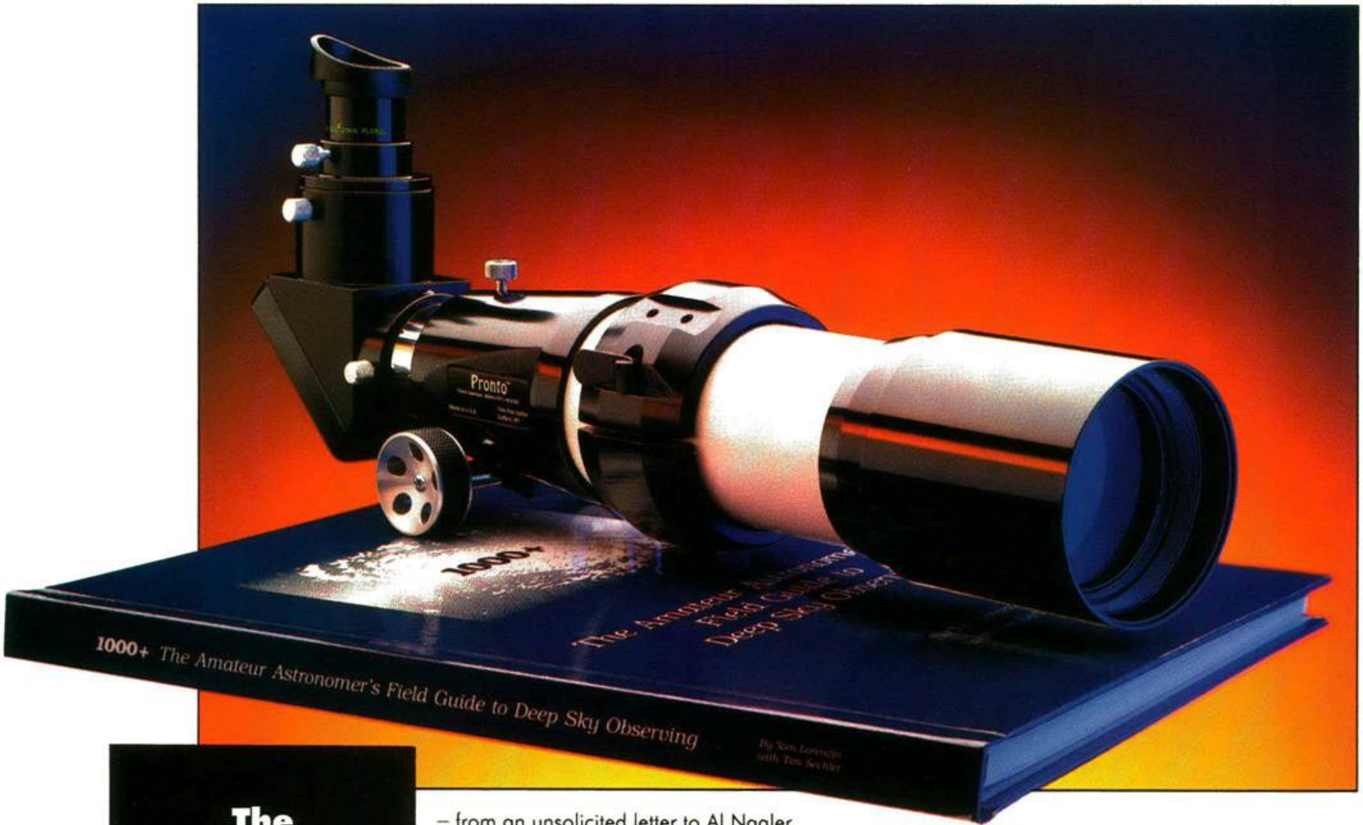
- Wanted a first telescope with superior optics, portability and value. I got what I asked for, wonderful little thing. J.P. - U.K.

- Well done! Saw the Owl and M108 in same field. T.J. - KS

- It was love at first sight, and it is just what I wanted. When I unpacked this instrument I said "this is a world class piece of art," using proved it. I have a winner here. M.B. - NY

PRONTO

Pronto: 70mm Ap., 480mm F.L., f/6.8 E.D. doublet, 2" diagonal, 21mm Plössl, adapter, mount ring, shoulder bag all std.


Pronto
1000+
1000+ The Amateur Astronomer's Field Guide to Deep Sky Observing
By Tom Lorenzin with Tim Sechler

The Little Scope That Could.

– from an unsolicited letter to Al Nagler

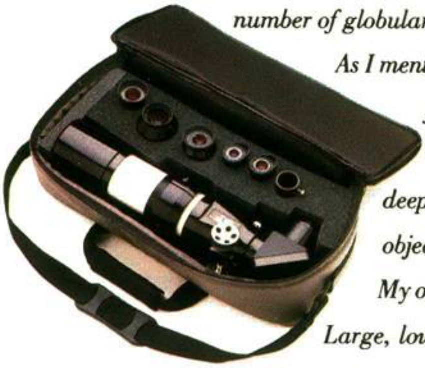
"Since I've been singing the praises of my Pronto to several people, I figure I'd better send you another note. During the November dark run, I used the Pronto on all or part of three nights. I made observations of 72 objects including a few double stars. Most of these observations were on a single night where the seeing was a little soft for the 6-inch refractor, but hardly noticeable in the Pronto. For me, the instrument's relative insensitivity to seeing is a great advantage, allowing good observing on nights I otherwise wouldn't go out.

The limiting stellar magnitude is between v=13.5 and v=14.0. This limiting magnitude is faint enough that a substantial number of globular clusters will be at least partially resolved.

As I mentioned before, the 30x eyepiece is my favorite for sweeping the Milky Way. I ended up using 50x for larger objects; 75x for 'ordinary' deep-sky viewing. A few high surface brightness objects were viewed to advantage at 110x, & I used 150x on double stars.

My observations show that from a true-dark site, the telescope is a real performer. Large, low surface brightness objects are routinely visible; even I was surprised by the visibility of NGC 147. Using the stars plotted on Uranometria, I traced the Andromeda galaxy to 4° length on two nights." – Brian Skiff, Author & Astronomer

Pronto photo of Eta Carina by Ralph Sieger



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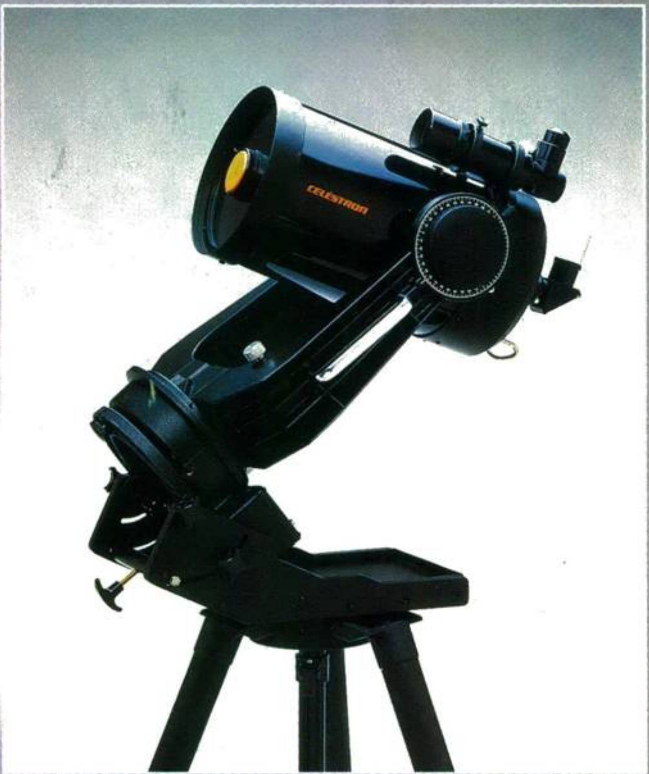
Take Home The Orion Nebula

The constellation Orion dominates the winter sky, its bright stars are easily recognized from the light polluted skies of urban areas. Nestled just below the three stars that make up the belt of Orion lies M42, the famed Orion Nebula. Discovered by Nicholas Peiresc in 1610, early observers called this the most remarkable object in the heavens. And for good reason. Viewed at low power, this huge stellar nursery fills the field seen through the telescope. Wisps of gas and dust fold back on the central stars seemingly protecting its stellar infants. Today, it is still a classic object that amateur sky gazers turn their telescopes to again and again.

Take home the Orion Nebula for yourself with the Celestron Ultima 8 telescope. Designed for the discriminating celestial photographer, the Ultima 8 uses a precision worm gear drive and Periodic Error Correction (PEC) for the ultimate in tracking accuracy. The massive polar shaft produces unparalleled stability. The unit comes standard with Starbright® coatings on the primary and secondary mirrors for the brightest images possible. And, the corrector plate is now made of optical crown glass! All this combines to produce the ultimate visual and photographic telescope — the Ultima 8! And, dozens of accessories expand the usefulness of this telescope for all forms of celestial photography.



Take home the Orion Nebula & other wonders of the universe with the Celestron Ultima 8.

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